DOCUMENT RESUME

ED 193 067 SE 032 970

AUTHOR	McPherson, Michael S., Ed.
TITLE	The Demand for New Faculty in Science and Engineering. Proceedings of the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers, 1979.
INSTITUTION	National Academy of Sciences - National Research Council, Washington, D.C. Commission on Human Resources.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	80
CONTRACT	SRS-79-13501
NOTE	257p.: Not available in hard copy due to copyright restrictions.
AVAILABLE FROM	Commission on Human Resources, National Academy of Sciences, 2100 Constitution Ave., N.W., Washington, DC 20418 (no price quoted).
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*College Faculty: Engineering: Engineering Education: *Engineers: *Labor Demands: Models: *Prediction: Science Education: *Scientists

ABSTRACT

Presented are selected analytical papers from a Workshop of Specialists in Forecasts of Demand for Scientists and Engineers, convened in 1979 in Washington, D.C. This workshop was part of a study by the Commission on Human Resources of the National Research Council charged with evaluating existing projections of the demand for young faculty in the various fields of science and engineering, assessing the potential damage to the research enterprise that might result from declines in the representation of young persons on science and engineering faculties, and recommending to the NSF and other federal agencies appropriate policies to counteract such damaging effects. Topics of papers in this volume include an examination of alternative approaches to modeling the demand for faculty, an analysis of the demand of faculty in specific fields of science and engineering, a critical review of the literature on age and scientific productivity, and an overview of issues raised in the volume and an assessment of the present state of understanding of those issues. (Author/CS)

THE DEMAND FOR NEW FACULTY IN SCIENCE AND ENGINEERING

Proceedings of the Workshop of Specialists
in Forecasts of Demand for Scientists
and Engineers, 1979

Commission on Human Resources
National Research Council

edited by
Michael S. McPherson

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1980

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The participants in the Workshop responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The work on which this publication is based was performed pursuant to Contract No. SRS79-13501 with the National Science Foundation.

Available from:

Commission on Human Resources
National Academy of Sciences
2100 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

PREFACE

The Committee on Continuity in Academic Research Performance of the National Research Council evaluated the potential impact of reduced hiring of new faculty on the vitality of academic research in science and engineering. The parameters influencing entry to and exit from research careers and factors influencing vitality and change in research performance were examined. The Committee's report "Research Excellence Through the Year 2000" was strongly influenced by early access to papers and discussions presented in a workshop of experts in Ph.D. labor market forecasting and analyses conducted by Committee members in the course of their work.

I am pleased that these contributors have made available the papers presented here. These papers will aid users of the Committee report in implementing or extending its findings. They should be useful as well in encouraging further research on problems of labor market forecasting and science productivity.

Robert M. Bock
Dean of the Graduate School
University of Wisconsin - Madison

Chairman
Committee on Continuity in
Academic Research Performance

ACKNOWLEDGMENTS

This volume was prepared under the auspices of the Commission on Human Resources of the National Research Council. Financial support was provided by the National Science Foundation.

Special thanks must go to Harold Goldstein, who organized the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers, for which several of the papers in this volume were prepared. Kathryn Swafford assisted in planning the Workshop and in later work on the papers.

The hard work of manuscript preparation and copy editing was ably and cheerfully handled by Milda Vaivada. Nancy Gardner assisted in this work. Kathy Drennan was responsible for general oversight of the project within the Commission. Other members of the Commission staff, especially Peter Syverson and Porter Coggeshall, assisted in the project at various points.

Finally, thanks must go to Dorothy Gilford and William C. Kelly for their work in planning the larger study undertaken by the Committee on Continuity in Academic Research Performance, which led to this volume, and to the Committee members for their support and encouragement regarding its preparation.

CONTENTS

PAGE

8

CHAPTER I

INTRODUCTION

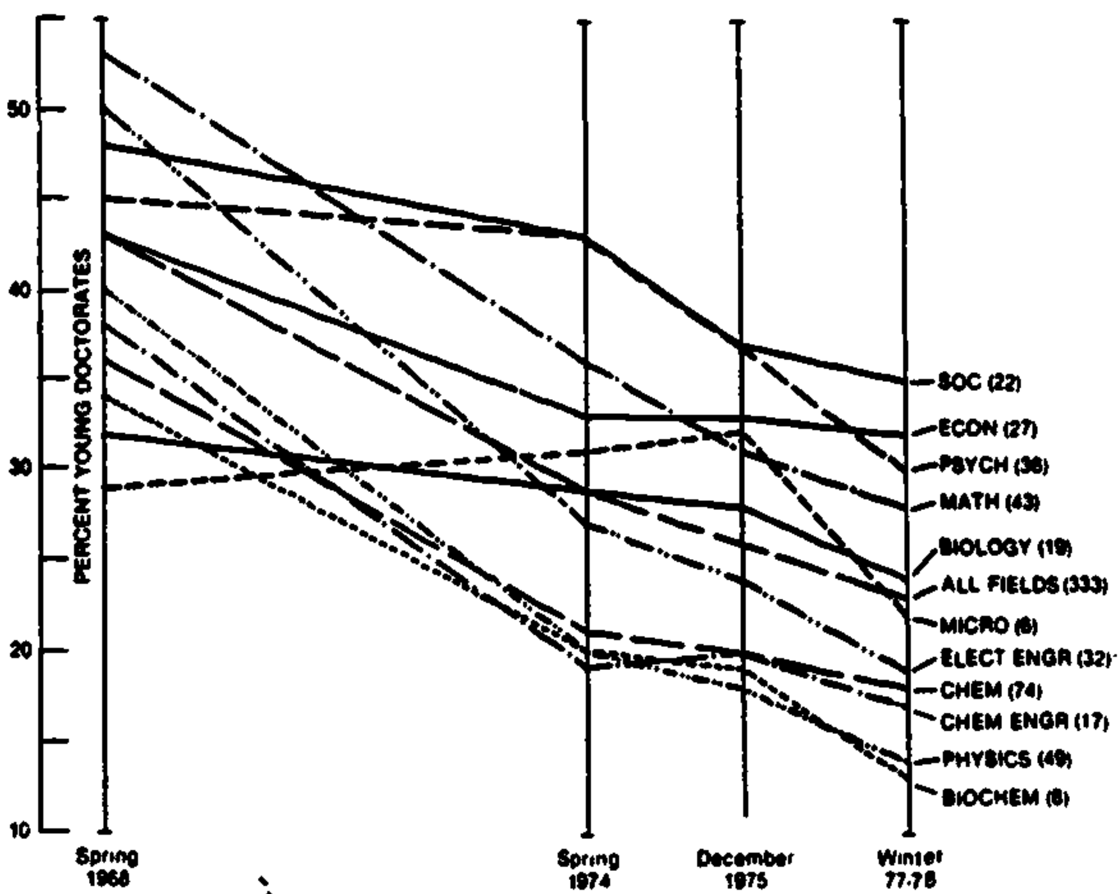
Michael S. McPherson
Williams College

The challenge of maintaining and strengthening the American research enterprise in an era of low or no growth in student populations and tight research funding has become a major preoccupation of scholars and policy makers concerned with American science and engineering. Among the worries is the potential danger that restrictions on the capacity of universities and colleges to hire new faculty may choke off an important source of vitality and creativity in the academic research enterprise. There is clear evidence, as shown in Figures 1.1 and 1.2, that significant declines in the representation of "recent" Ph.D.'s (within seven years of the degree) on university faculties in a number of science and engineering fields have already occurred. The prospect of low or no growth in the higher education system coupled with unusually low retirement rates over the next ten years has led many observers to expect these trends to continue and worsen.

As part of its continuing effort to monitor and evaluate this potential problem, the National Science Foundation in early 1979 asked the National Academy of Sciences to undertake a study of future demand for faculty, and the potential consequences for research effectiveness of further declines in hiring rates. In response to this request, the Commission on Human Resources of the National Research Council called together the Committee on Continuity in Academic Research Performance, chaired by Dr. Robert M. Bock, to perform the study. The Committee was charged with evaluating existing projections of the demand for young faculty in the various fields of science and engineering, with assessing the potential damage (if any) to the research enterprise that might result from declines in the representation of young persons on science and engineering faculties, and with recommending to the NSF and other federal agencies appropriate policies to counteract such damaging effects as were anticipated.

FIGURE 1.1

TRENDS IN PROPORTION OF YOUNG DOCTORATES AMONG FULL-TIME FACULTY
IN SELECTED SCIENCE AND ENGINEERING DEPARTMENTS
SPRING, 1968-WINTER, 1977-78



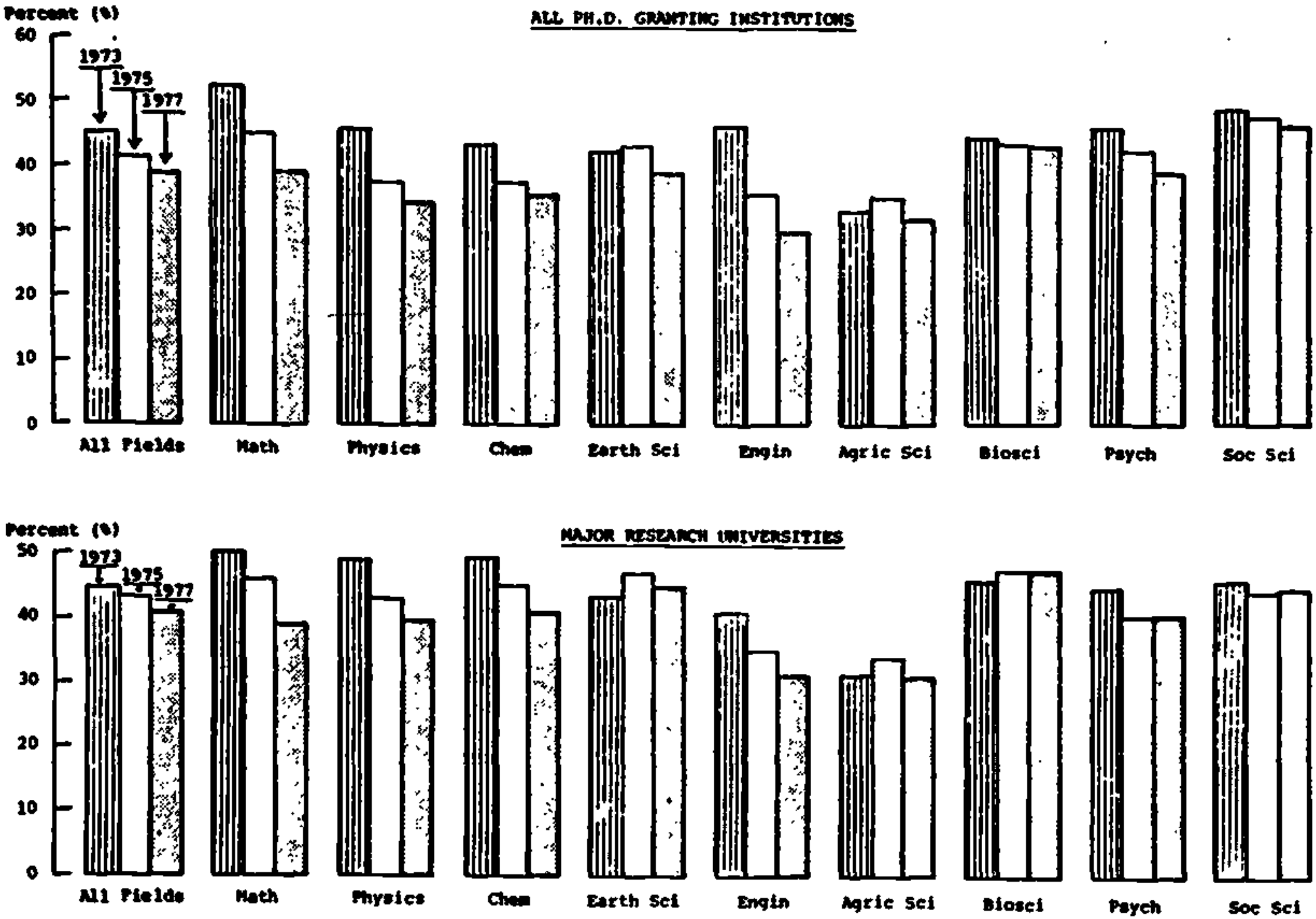
NOTE 1. Numbers in ( ) following fields refer to the numbers of departments that responded to all four surveys

NOTE 2. The lines connecting the points are intended as visual aids only. The values for years between surveys may not lie on these straight lines

Source: Atelsek and Gomberg (1979), p. 10

FIGURE 1.2

PERCENT OF TOTAL DOCTORAL FACULTY IN 1973, 1975, and 1977 WHO HAVE EARNED THEIR DOCTORATES IN THE PRECEDING SEVEN YEARS



Source: National Research Council, Survey of Earned Doctorate Recipients, 1973, 1975, 1977

The Committee concluded that substantial declines in the rate of hiring of new faculty were quite likely in some science and engineering fields and that such declines, if allowed to occur, might seriously impair the effectiveness of the academic research effort in those fields. The Committee recommended that the National Science Foundation combat this problem by initiating a program of "Research Excellence Awards" in selected fields. These would be five-year, nonrenewable awards to tenured or non-tenured faculty members nominated by their departments. The awards would provide partial salary support to award recipients, with the university funds thereby released to be directed to the hiring of additional new faculty in the recipient's department. A full account of the Committee's analysis and recommendations can be found in its report, Research Excellence Through the Year 2000: The Importance of Maintaining A Flow of New Faculty into Academic Research.

In the course of its work, the Committee asked a number of experts in relevant fields to provide papers bearing on its concerns. Many of these papers were first presented at a Workshop of Specialists in Forecasts of Demand for Scientists and Engineers, which was convened by the Committee on April 30-May 1, 1979 in Washington, D.C. Other analytical papers were prepared later at the Committee's request, some authored by workshop participants and others by committee members.

The present volume makes a selection of these analytical papers more widely available. The papers not only provide important analytical background for the analysis of policies toward academic research personnel, but also make important and original contributions to the analysis of faculty labor markets. A major reason for making them available is the hope that they will help encourage further research on this important and difficult range of problems.

The early papers in the volume focus on alternative approaches to modeling the demand for faculty. The papers by Charlotte Kuh and Roy Radner and by the National Science Foundation represent attempts by the respective authors to extend their well-known earlier projection studies to focus more explicitly on the demand for new faculty in science and engineering. The

Kuh-Radner results seem to point to a somewhat larger decline in academic hiring opportunities in science and engineering than do the NSF results, and the two papers both make attempts to account for this difference. These accounts are, however, themselves somewhat hard to reconcile, and Donald Hernandez in chapter IV provides an instructive comparison of the structure of the two models, and a helpful methodological analysis of the problems encountered in attempting to arrive at a conclusive explanation for differences in the projection results.

In chapter V, Richard Freeman introduces another important set of modeling issues, by attempting to demonstrate econometrically the importance of accounting for the responses of individuals and institutions to economic incentives in modeling the market for college faculty. The paper breaks new ground, especially in its analysis of the responses of not-for-profit institutions to economic incentives.

Chapters VI and VII turn from general issues in the modeling of faculty demand to analysis of demand for faculty in specific fields of science and engineering. Lee Grodzins' paper extends his earlier writings on the job situation in physics by developing a long-term model of the demand for physics faculty and by analyzing the expected effects of government programs designed to increase the demand for faculty. As in his other work, Grodzins' paper combines the employment of an unusually rich data base with the use of the simplest possible modeling framework. Charlotte Kuh's paper reports on the application of the basic Radner-Kuh model of faculty demand to data for the several broad fields of science and engineering. The results confirm the familiar Radner-Kuh projection of a significant shortage of openings for new faculty, but with some interesting and thought provoking surprises. These early results on projections for specific fields are likely to stimulate considerable controversy and further research efforts.

Barbara Reskin's critical review of the literature on age and scientific productivity in chapter VIII moves the focus from discussion of projected numbers of young faculty in science and engineering to assessment of the significance for scientific research of a changing age distribution of researchers. Her survey indicates that, contrary to popular myth, youth *per se* is not strongly correlated with available measures of productivity for individual scientists. If a flow of new faculty matters to science productivity, it apparently is not because "young" scientists are inherently better than "old" scientists. It is more likely that the hiring of young faculty has served as a vehicle for the infusion of new ideas, techniques and research directions into academic departments, and as the occasion for departments to revise their staffing in light of changes in research interests and needs. This diagnosis differs importantly from one which puts the emphasis on youth as such, and points to rather different policy implications.

The concluding chapter by Fred Balderston and Michael McPherson offers an overview of the issues raised in the volume and an assessment of the present state of our understanding of those issues. Drawing heavily on the discussion at the Forecasting Workshop, the paper identifies areas needing further research and discusses the implications for intelligent policy making of the limitations on our present knowledge.

CHAPTER II

NATIONAL SCIENCE FOUNDATION MODELS OF THE FLOWS OF ACADEMIC PERSONNEL

Division of Science Resources Studies
National Science Foundation

Since 1968 the National Science Foundation (NSF) has monitored the level of representation of younger scientists and engineers on the faculties of universities and colleges. A succession of Foundation surveys has recorded an unbroken downward trend in the proportion of science and engineering doctoral faculty who have held their degrees for seven years or less (National Science Foundation, 1968, 1975; Atelsek and Gomberg, 1976, 1979).[1/] Projections made by Roy Radner and Charlotte Kuh indicate further declines in the proportion of younger faculty through 1990 (Radner and Kuh, 1978). The Foundation took two steps to evaluate the Radner-Kuh and related forecasts and to determine whether ameliorative federal actions are needed to increase the number of younger faculty. The first was to have its own staff project the future representation of younger science doctorates in academia. The second involved requesting the National Academy of Sciences to study the broad policy issue of the role of younger scientists and engineers and to recommend whatever federal programs might be needed to ensure an adequate level of employment of younger faculty. This request led to the creation of the Committee on Continuity in Academic Research Performance and to the convening of the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers. This short paper describes the projection activities of NSF staff.

I. Projections Reported at the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers

At the April 30-May 1, 1979 meeting of the Workshop, NSF staff presented projections of the proportion of academic science and engineering doctoral

[1/] A new survey of "Research Participation and Other Characteristics of Recent Science and Engineering Faculty" will be conducted in spring 1980.

staff primarily engaged in teaching,[2/] who in 1987 will have held their degrees for seven years or less. Subsection A briefly outlines the steps which produced these projections. Subsection B discusses the data and assumptions used in making these estimates, and Subsection C compares the results of these early NSF forecasts with those from the Radner-Kuh model. The estimates were intended for interim use until NSF staff could develop a more sophisticated computer model to simulate the flow of personnel through academia. The last section of this paper provides a progress report on this model.

A. <u>Steps in Projecting 1987 Employment of Recent Doctorates</u>

The NSF model discussed at the Workshop (NSF-1) produced 1987 estimates through the following steps. First, the 1977 academic base population was divided into four groups based on possession of a Ph.D. and tenure status. Those without tenure were then split into those who were assumed to receive tenure by 1987 and those who would not. The latter group was assumed to leave the academic population before 1987. The number of those who either held tenure in 1977 or would receive it in subsequent years was then reduced to reflect deaths and retirements between 1977 and 1987. This "surviving 1977 population" was subtracted from projected 1987 employment to arrive at an estimate of the total number of staff employed in 1987 who were not employed ten years earlier. This estimate was then multiplied by the proportion of hires assumed to have doctorates to arrive at H, the number of doctorates employed in 1987 who were not in the 1977 base population. On the assumptions (a) that annual hiring is constant over the projection period, (b) that each person hired remains seven years and then either receives tenure or leaves, and (c) that the fraction receiving tenure is a constant (t), the following formula expresses the estimated ratio (R) of recent doctorates (those holding degrees seven years or less) to total doctorates in 1987. Doctorate staff employed in 1977 and 1987 are represented by S.

$$R = \frac{H(1-.3t)}{H+S}$$

[2/] Staff primarily engaged in teaching, rather than faculty, served as the subject of these projections because the only readily available information on the 1977 population was contained in <u>Human Resources for Scientific Activities at Universities and Colleges, January 1977</u>, NSF 77-321. This publication reports staff but does not distinguish between those who have faculty status and those who do not. Furthermore, postdoctorates are included in staff primarily engaged in research. To exclude postdoctorals, only staff primarily engaged in teaching were the base population for NSF-1.

The term (-.3t) removes from H that group who were hired in 1977, 1978, and 1979 (who would not be recent in 1987 because they would have held their doctorates more than seven years) and who are still present in 1987 because they received tenure.[3/]

B. Chief Data Sources and Assumptions of NSF-1

(1) Characteristics of the Academic Staff Base Population in 1977

The January 1977 NSF Survey of Scientific and Engineering Personnel Employed at Universities and Colleges provided the number of full-time staff primarily engaged in teaching divided into those with Ph.D.'s and those without. About 67 percent of the 155,000 in the base population held doctorates. It was assumed that the 1977 proportions of doctoral and nondoctoral staff with tenure were equal to the fractions found in the NSF Survey of Faculty Research Activities, Spring 1974 (National Science Foundation, 1975). These proportions were 71 percent and 54 percent, respectively. (Data later available from the National Academy of Sciences' 1977 Survey of Doctorate Recipients (National Research Council, 1978)) indicate that the fraction of doctoral faculty with tenure was approximately 70 percent.

(2) Projection of 1987 Employment

The 1977-87 relative change in employment of the base population was assumed to be equal to that reported in Projections of Science and Engineering Doctorate Supply and Utilization, 1982 and 1987 (NSF 79-303). For that report future academic utilization was estimated with the use of regression equations which relate employment to baccalaureate awards (used as an index of demand for academic staff). The report projects 1987 employment for each of five major fields: the physical, mathematical, life, and social sciences and engineering. (See Appendix for the projection equations.) An aggregate 1977-1987 growth rate for all fields combined was derived for use with NSF-1.

Regression equations, when used as a basis for projecting academic employment, offer an advantage over the most often used alternative technique

---

[3/] This formula reflects the specific characteristics of a ten-year projection period. (The three years 1977-1979 are .3 of the ten years between 1977 and 1987.)

which is to assume that student-staff ratios will remain constant during a projection period. This advantage stems from the fact that regressions relate employment to degrees, or other independent variables, at the margin. Thus each additional 100 baccalaureate awards are statistically associated with the employment of a particular number of additional staff.[4/] This is in contrast to assuming constant student-staff ratios which imply that the average relation between students and staff observed at the time the projections were made will remain unchanged. The steady rise in the academic employment of scientists and engineers since 1974--a period when science and engineering degrees have not grown--raises significant questions about assuming that the ratio of students to staff will remain constant during a projection period.

Baccalaureate degrees, the demand variable in the regression equations, were projected for the four science fields by assuming that trends existing as of 1976 in the numbers of baccalaureate degrees awarded by field and sex would continue through 1987.[5/] The future rate of change, however, was assumed to be one-half the existing rate. The assumption that existing trends would continue was based on the judgment that the factors that produced them would still be operational during the projection period. These include a continued shortage of jobs for social sciences baccalaureates and continued growth in female participation in science. For engineering, future awards were projected with an approach that related engineering baccalaureates to supply and demand factors.

[4/] If the values of all variables in the regression are transformed into logarithms, the coefficients may be interpreted as elasticities which equal the ratio of the percentage change in the dependent variable associated with the percentage change in the independent variable.

[5/] Trends were assumed to begin either in 1960 or whenever the number of baccalaureate awards began a clear period of growth or decline. The only exception is male social science baccalaureates where a 1972-76 period is used rather than 1974-76. Although degrees did not begin to drop until 1974, the fall was so precipitous that use of the 1974-76 period as a basis for extrapolation would lead to extremely low projections of 1987 male social science baccalaureates. The following years mark the beginning of the trends used in projection of baccalaureate degrees: physical sciences, men--1966 and women--1969; mathematical sciences, men and women--1970; life sciences, men and women--1960; social sciences, men--1972 and women--1974.

The decision to halve existing rates was based upon the historical relationship between science and engineering baccalaureates and the sum of all baccalaureates and first-professional degrees which had remained in a narrow 28-32 percent band over the past 21 years. Estimated 1987 baccalaureate and first-professional degrees were obtained from projections produced by the National Center for Education Statistics (NCES, 1978). The 1977-87 growth of science baccalaureates was adjusted until the sum of these awards and engineering degrees fell within this 28-32 percent range. The NCES Projections were produced with a demographically based model. Consequently, the NSF science and engineering baccalaureate projections, although based primarily on attenuated extrapolations, implicitly considered demographic factors.

Baccalaureates are not an ideal index of demand, but are a Proxy for better measures of faculty requirements such as enrollments by field. The latter, unfortunately, are unavailable at the undergraduate level. In addition, numbers of degrees awarded may not adequately account for future demand for staff for research activities. This problem could arise if requirements for teaching and research activities do not maintain the relation which they have had in the past.

(3) Projection of Attrition of 1977 Staff Due to Death and Retirement

A weighted average of the attrition rates used for the five science and engineering fields in NSF 79-303 was applied to the 1977 academic labor force in NSF-1 to account for deaths and retirements through 1987. NSF 79-303 used age-specific mortality rates obtained from the Teachers Insurance and Annuity Association (TIAA) and 1973 field-specific age distributions from the American Council on Education (ACE). Retirement was assumed to occur at age 66. It should be noted that the population insured by TIAA has lower mortality rates than does the general population. Choice of a retirement age of 66, rather than 69 or 71, has a somewhat smaller effect on estimated openings. The comparison below of NSF-1 with the Radner-Kuh model provides quantified illustrations of the sensitivity of NSF-1 to these and other assumptions.

(4) Proportion of Staff Hires with Doctorates

The fractions of 1977-1987 hires with doctorates in the five science and engineering (S/E) fields, as estimated in NSF 79-303, were weighted, aggregated (which produced a value of .84) and applied to total hires in NSF-1. By contrast, only about 65 percent of 1977 S/E staff primarily engaged in teaching held doctorates. The published report assumed all new staff in universities would have doctorates. For hires in 2-and 4-year schools, the report used the findings of an ACE survey (Atelsek and Gomberg, 1978) which obtained estimates by field of the proportions of 1966-77 appointees who had or would soon receive doctorates. The assumption that the credentials of staff would be upgraded during the projection period had a substantial effect on estimated openings.

(5) Transfers of Staff Between Academia and Other Sectors

It was assumed that there would be no such transfers except for staff who are forced to leave academia for failure to receive tenure. This simplifying assumption was necessary because of a lack of data. Evidence available since NSF-1 was presented indicate that such voluntary mobility is fairly small and would not strongly affect the results of NSF-1.

(6) Proportion of New Staff Receiving Tenure

NSF-1 arbitrarily assumed this proportion would be one-half. The projections are very sensitive to this assumption.

(7) Length of Pre-Tenure Probationary Period

This was put at seven years. In the past, this has been the standard period of probation although anecdotal information suggests this period has become longer at many schools. Those failing to receive tenure are assumed to leave academia before the start of the next academic year. In conjunction with the proportion of new staff assumed to receive tenure, this assumption can have a strong effect on projected openings, particularly for projections covering a short period.

C. Comparison of Results from NSF-1 and the Radner-Kuh Model

NSF-1, using the assumptions outlined above, projects that 33 percent of doctoral science and engineering full-time staff primarily engaged in teaching in all colleges and universities will have held their degrees for seven years or less in 1987. The most comparable figure from the Radner-Kuh paper, Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000 (1978), pertains to the fraction of doctoral faculty in all fields, including non-science, who will be 35 years of age or younger in 1986. This fraction is projected to be 14 percent. The two estimates are far apart and seemingly point to quite different future levels of younger faculty representation. Analysis, however, suggests that all but a few of the 19 percentage points separating the two estimates can be accounted for by differences in assumptions and definitions used in the two models. These sources of divergence, which are summarized in Table 2.1, are explained below.[6/]

The two models differ in how they account for the three elements of attrition--death, retirement, and failure to receive tenure. The use of TIAA mortality rates for NSF-1 lowered the projected representation of young doctoral faculty two percentage points below what it would have been if rates for all males had been used as in the Radner-Kuh model. (This is the only important assumption tending to decrease the estimated percentage of younger faculty of NSF-1 below that of the Radner-Kuh model.) With an opposite effect, assuming a retirement age of 66 in NSF-1 raised the projected younger doctorate representation by one percentage point above what would have been obtained if the Radner-Kuh assumption of retirement at 69 had been used. The effects of the different treatment of death and retirement roughly cancel each other so that only the last element of attrition is important in explaining the differences in projection results. NSF-1 assumes that only one-half of new staff are retained after seven years whereas Radner-Kuh projects that over 70 percent of the 1978 cohort of new staff will be in academia in 1987.[7/] If NSF-1 had used the higher

[6/] In a paper prepared for the workshop, "Reconcilable Differences?" Radner and Kuh presented additional projections that used data from the Comprehensive Survey of Doctoral Scientists and Engineers (National Research Council, 1976). In this paper, the authors projected that 19.5 percent of faculty would be of academic age seven years or less in 1987.

[7/] This percentage varies in the Radner-Kuh model by entering cohort.

TABLE 2.1

DIFFERENCES BETWEEN NSF-1 AND RADNER-KUH
PROJECTIONS OF "RECENT" FACULTY RATIOS

	NSF-1	Radner-Kuh	Difference
1986-87 Recent Faculty Percentage	33%	14%	19%

Source of Difference	Estimated Difference from NSF Projection Model (In Percentage Points)	Cumulative Difference
TOTAL........................	-19	--
Definitions of "Recent" and "Young" Faculty................	-5	-5
Proportion of Nontenured Staff Retained.................	-7	-12
Absence of Staff Upgrading.......	-4	-16
Number of Academic Staff Employed.......................	-3	-19
Death Rates......................	+2	-17
Retirement Age...................	-1	-18
Unaccounted For..................	-1	-19

Source: National Science Foundation

retention rate, its estimate of the 1987 ratio of recent to total doctorates would have been reduced by about 7 percentage points, or from 33 percent to about 26 percent.

Another important factor contributing to the difference in projections is the fraction of projected hires who have doctorates. The Radner-Kuh model assumes that this proportion will be equal to the corresponding fraction for all staff in the base year--one-half for all fields combined. In contrast, the NSF model assumes, on the basis of data from NSF surveys, that colleges and universities will upgrade their staff during the projection period by hiring doctorates for about 85 percent of their staff openings. If NSF-1 had held the doctoral hiring proportion to the current two-thirds of science and engineering staff with doctorates, its projected ratio of recent to total doctoral staff would have been four percentage points lower, or 29 percent.

In addition to the differences in assumptions stated above, the Radner-Kuh model distributes doctorates by age instead of years since degree. The Radner-Kuh staff group, 35 years of age and younger, is the closest to the "recent" category (those holding a doctorate seven years or less) used in the NSF-1. Because S/E doctorates receive their degrees on average at age 30, this group is smaller than the total of recent doctorates. This difference in definitions reduces the Radner-Kuh estimate by about five points from what it would have been if 37 were used as the boundary of this age group.[8/]

In summary, if the Radner-Kuh projection is adjusted to reflect those 37 years of age and younger, rather than 35, it would indicate that about 19 percent of doctoral faculty would be recent in 1986. Similarly, if NSF-1 had assumed a higher retention rate of .7, instead of .5, and had not accounted for staff upgrading, it would have projected the representation of more recent doctorates to be about 22 percent in 1987. The remaining three percentage points difference between the projections chiefly stems from the assumption of NSF-1 that employment will grow by six percent between 1977 and 1987 and the Radner-Kuh assumption of about one percent growth.

[8/] This assumes that faculty are evenly distributed by age between the 14 percent Radner and Kuh projected to be 35 years of age or younger and the 26 percent projected to be 40 or younger.

II. Development of a Computer Model to Simulate the Employment Flows of Scientists and Engineers Through Academia

Since the meeting of the Workshop in spring 1979, Foundation staff have developed a computer model to simulate the flow of science personnel through academia. Current efforts center on improving methods used to project future numbers of academically employed scientists and engineers, a key element in the model.

A. Description of the Computer Simulation Model

The new computer simulation model (which will be referred to as NSF-2) incorporates a number of technical improvements over NSF-1. NSF-2 also benefits from data that were not available at the time of the Workshop. The first part of this section outlines the structure of the computer model and the second briefly outlines work toward improving the technical basis of projecting future academic employment.

NSF-2 distributes an academic population by biological age. This distribution is updated to reflect the entry of new personnel and the aging and changes in status, or transitions, of veteran staff. All transition probabilities are related to age. These transitions consist of promotion to tenure and separation from the population due to any of four reasons--death, retirement, failure to receive tenure, and voluntary separation to accept a position in another sector. The model does not account for mobility from one academic institution to another so long as the employees of both are included in the population. All transition probabilities, other than for death, can vary during the projection period. For example, the proportion of staff receiving tenure after a probationary period could be set at .65 for 1980 and .55 for 1983. The probationary periods can also be set at varying lengths. Future developmental work will attempt to account for the effects of the academic labor market upon the length of probationary periods as well as upon the probabilities of promotion to tenure and voluntary mobility between academia and other sectors.

NSF-2 has four subpopulations based on tenure status and possession of a doctorate. All entrants, whose age distribution can be varied during the projection period, are assumed to be inexperienced and are entered into one of the two untenured subpopulations. The fraction of new staff who enter the doctoral, untenured subpopulation is assumed to be unchanged during the projection period. Those members of the untenured groups who are not promoted to the tenured groups after probationary periods leave the population by the start of the next projection year. Promotion rates can be different for the doctoral and nondoctoral subpopulations. In regard to the other transition probabilities, death rates and retirement age are assumed to be the same for doctorates and nondoctorates (only tenured staff reach retirement age and mortality is very low for those young enough to be untenured), but the age-specific rates of voluntary separations to non-academic jobs can be different for each of the four subpopulations.

Tabulations of data from the National Academy of Sciences Survey of Doctorate Recipients (National Research Council, 1978) have provided tenure and age characteristics of the 1977 doctoral academic population that were not available for NSF-1. These tabulations have also allowed estimation by field of the proportion of untenured doctorates who received tenure between 1973 and 1977 as well as of the proportion of tenured doctoral staff who left academia for employment in other sectors. These historical proportions are assumed in NSF-2 to remain in effect during the entire projection period. Results from the annual NAS Survey of Earned Doctorates permits estimation of the age distribution of new doctoral faculty. No data are available on the age distribution of the 1977 population of nondoctorates. Similarly, no direct information exists on the average age of new nondoctoral staff. NSF-2 assumes that tenured nondoctorates are evenly distributed by age and that nondoctorates begin academic employment at age 25.

B. Projection of Future Academic Employment

An effort is underway to improve the technical basis for projecting future academic employment through respecification of the regression equations that are used to estimate future staffing. Three additional observations on academic employment have become available (National Science Foundation. 1979b) since the preparation in 1977 and 1978 of Projections of Science and Engineering Doctorate Supply and Utilization, 1982 and 1987 (1979a), which provided the staffing growth rate used for NSF-1. The additional data provide additional degrees of freedom which have permitted adding independent variables, such as R&D spending and enrollment for advanced degrees, to the regressions that explain employment by field. Previously, these regressions have used only baccalaureate awards and trend variables as independent variables.

Other efforts are being made to improve methods of estimating future bachelor's degrees by fields. As one approach, various autoregressive equations are now being tested to evaluate their performance in explaining numbers of degrees awarded in the past. With these equations, degrees in a year are regressed against three or more independent variables that include degrees lagged one year, degrees lagged two years, and a demand variable. In some autoregressive equations, the parameters are being estimated using normalized values of the dependent variables derived by dividing the values of the degree variables by the numbers of high school graduates four years earlier. This controlled for any effects that the size of baccalaureate cohorts may have had upon trends in awards (See Freeman and Leonard, 1978).

The results of these efforts will be reported in future publications of the NSF Division of Science Resources Studies.

REFERENCES

Atelsek, F. J. and I. L. Gomberg. Young Doctorates Faculty in Selected Science and Engineering Departments, 1975 to 1980. Higher Education Panel Report, No. 30, Washington, D.C.: American Council on Education, August 1976.

_____. New Full-Time Faculty 1976-77: Hiring Patterns by Field and Educational Attainment. Higher Education Panel Report, No. 38. Washington, D.C.: American Council on Education, March 1978.

_____. Young Doctoral Faculty in Science and Engineering: Trends in Composition and Research Activity. Higher Education Panel Report, No. 43, Washington, D.C.: American Council on Education, February 1979.

Freeman, R. and J. Leonard, "Autoregressive Degree Pattern: Evidence of Endogenous Cycles in the Market?" Industrial Relations Research Association Series: Proceedings of the Thirtieth Annual Winter Meeting, 1978, pp. 10-19.

National Center for Education Statistics. Projections of Education Statistics to 1986-87. Washington, D.C.: United States Government Printing Office, 1978 (NCES 78-403).

National Research Council, Commission on Human Resources. Doctoral Scientists and Engineers in the United States - 1975 Profile. Washington, D.C.: National Academy of Sciences, 1976.

_____. Science, Engineering, and Humanities Doctorates in the United States, 1977 Profile. Washington, D.C.: National Academy of Sciences, 1978.

National Science Foundation, Support and Research Participation of Young and Senior Academic Staff, 1968. Washington, D.C.: 1968 (NSF 68-31).

_____. Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation and Tenure. Washington, D.C.: 1975 (NSF 75-302).

_____. Survey of Scientific and Engineering Personnel Employed at Universities and Colleges, 1977. Washington, D.C.: January 1977.

_____. Human Resources for Scientific Activities at Universities and Colleges. Washington, D.C.: January 1977 (NSF 77-321)

_____. Projections of Science and Engineering Doctorate Supply and Utilization, 1982-1987. Washington, D.C.: 1979a (NSF 79-303)

_____. Academic Science: Scientists and Engineers. Washington, D.C.: January 1979b (NSF 79-328).

Radner, R. and C. V. Kuh. Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000. A Report to the Carnegie Council on Policy Studies in Higher Education, October 1978.

APPENDIX

Projection of 1987 Academic Employment

The projections of 1987 academic employment were based on the past statistical association between staff and baccalaureate degrees. For each field, regression analysis related the number of full-time academic staff, including nondoctorates, in January of a given year to one or more of the independent variables listed below.

BACC--the total number of baccalaureates awarded in a single broad field

BACC(1)--the total number of baccalaureates awarded in all S/E fields except the social sciences

BACC(2)--the total number of baccalaureates awarded in all S/E fields

TIME--a trend variable equal to the number of the observation (e.g., one, for the first observation)

BACC/TIME--the variable BACC divided by the trend variable

BACC(1)TIME--the variable BACC(1) divided by the trend variable

There were eight observations for the period 1965 to 1976. Different equation specifications were tested to determine which variables best explained past variation in academic employment. Those specifications which seem most consistent with what is known about the types of courses taken by students in different fields and which had the best statistical properties were used in the projections. For each field the equation listed below was used to project total staff, except in the social sciences in which employment was assumed to be unchanged between 1977 and 1987. In the physical and life sciences, specifications using BACCS(1) (all science and engineering (S/E) baccalaureates less the social sciences) were chosen for the projection equations to reflect the service function performed by faculty in these two fields for students majoring in other S/E fields. (It is assumed that social sciences undergraduates do not take natural sciences courses as frequently as do other S/E students.) BACC(2) (all S/E baccalaureates) appears in the projection equations for the mathematical sciences on the basis of the assumption that faculty in this field instruct all S/E undergraduates. On the other hand, few nonengineering students enroll in engineering courses so BACC (in this case, baccalaureates in engineering only) was the independent variable in the projection equation. In this field, as well as in the physical sciences, trend variables were also used. In the equations below, the numbers in parentheses refer to t-statistics.

```
Physical sciences staff = 22,941 + 0.052 BACC(1)
                           (7.7)      (2.1)
  +312 TIME  -0.056 BACC(1)/TIME
     (2.6)        (-7.5)
          R = .99  Durbin-Watson
                   statistic = 2.8

Engineering staff = 17,799 + .130 BACC
                     (8.7)      (2.8)
  +.124 BACC/TIME
      (-7.5)
          R = .96  Durbin-Watson
                    statistic = 2.0

Mathematical sciences staff =  1,099
                               (-.6)
  +.080 BACC(2)
      (11.8)
          R = .96  Durbin-Watson
                    statistic = 1.3

Life sciences staff = 6,838 + .246 BACC(1)
                       (1.6)     (8.3)
          R = .92  Durbin-Watson
                    statistic = 2.5

Social sciences staff = 12,279 + .137 BACC(2)
                         (2.0)       (5.9)
          R = .85  Durbin-Watson
                    statistic = 1.4
```

CHAPTER III

RECONCILABLE DIFFERENCES?

An Examination of Alternative Projections of Academic Demand for Recent Science and Engineering Ph.D.'s in the 1980's*

Charlotte Kuh
Harvard Graduate School of Education

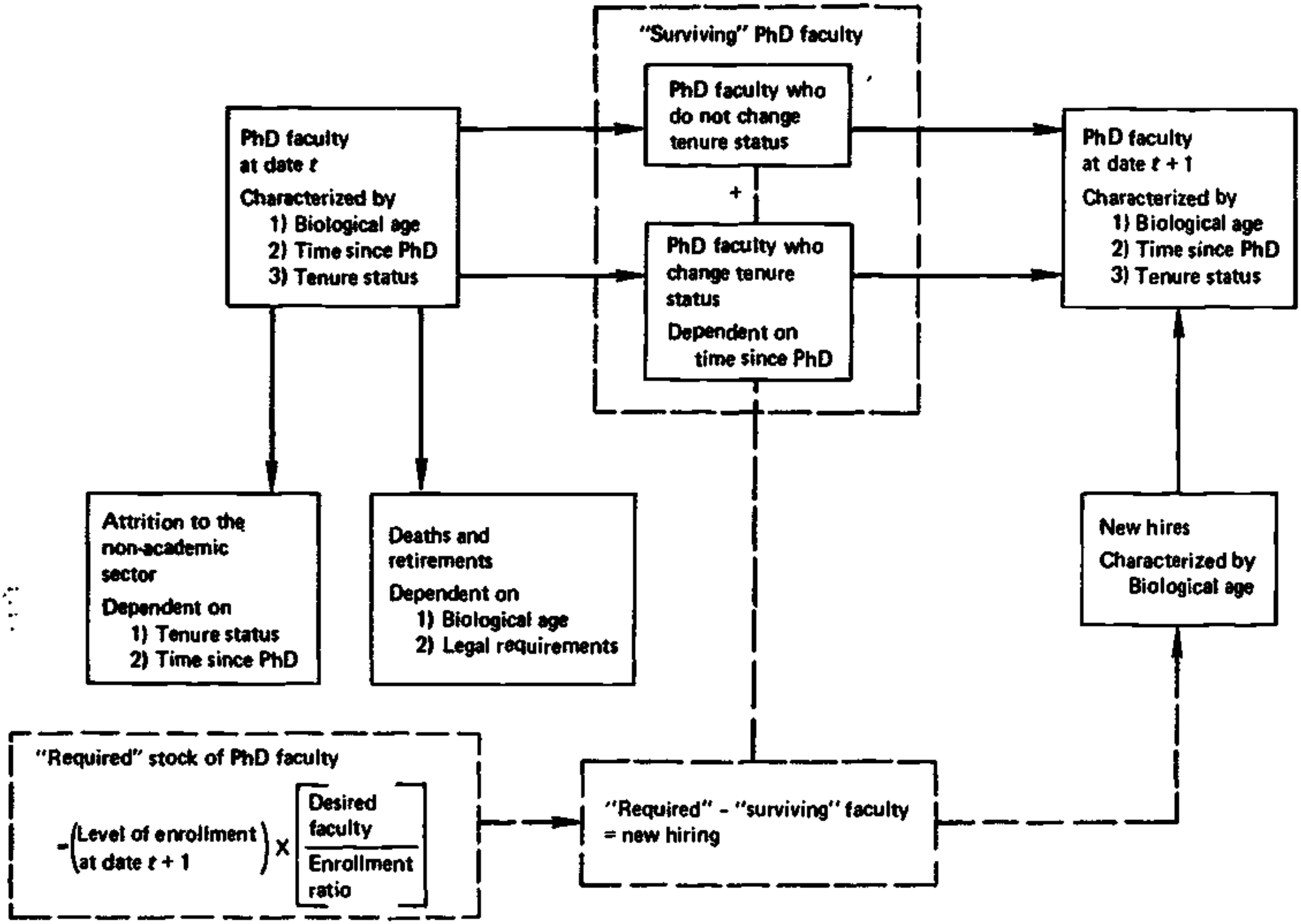
Roy Radner
University of California, Berkeley and
Kennedy School of Government, Harvard

1. Introduction

We have been asked to compare, contrast, and comment on the National Science Foundation (NSF) model that forecasts the supply and utilization of doctoral scientists and engineers (National Science Foundation, 1979) with the model that we and Luis Fernandez have developed to forecast academic demand for doctorates (Kuh and Radner, 1977; Fernandez, 1978). The two models plainly differ in scope and emphasis -- that of the NSF being broader in terms of coverage of the entire labor market and narrower in that it restricts itself to science and engineering. We intend to focus on the young investigator problem in this paper. In particular, we would like to compare the predictions from an economic-demographic model we have developed to the predictions from the NSF model of academic demand for recent doctoral scientists and engineers.

Differences in predictions of different models may come from three primary sources; 1) differences in methodology, 2) differences in assumptions concerning parameters, 3) differences in baseline data. This discussion will focus on the first source, since the second and certainly the third should be objectively ascertainable. The Kuh-Radner model is essentially a cohort survival model. It is dynamic and tracks the evolution of academic demand over a 25-year period. A flow diagram that lays it out is presented in Figure 3.1. A similar diagram for the NSF

*We wish to thank David Bussard and Bernard Morris for research assistance. This paper is based on research supported in part by the National Science Foundation.


"Surviving" PhD faculty
PhD faculty who do not change tenure status
+
PhD faculty who change tenure status
Dependent on time since PhD
PhD faculty at date t
Characterized by
1) Biological age
2) Time since PhD
3) Tenure status
PhD faculty at date t + 1
Characterized by
1) Biological age
2) Time since PhD
3) Tenure status
Attrition to the non-academic sector
Dependent on
1) Tenure status
2) Time since PhD
Deaths and retirements
Dependent on
1) Biological age
2) Legal requirements
New hires
Characterized by Biological age
"Required" stock of PhD faculty
= (Level of enrollment at date t + 1) X [Desired faculty / Enrollment ratio]
"Required" - "surviving" faculty = new hiring

projection model for new doctoral hires is presented in Figure 3.2. The basic elements of both models are similar. The demand for new academic staff is derived from the changes in the number of students to be served, and replacement demand resulting from death, retirement, and other sources of attrition. It is also necessary to predict what proportion of new academic staff will have doctorates. The NSF model presents projections for the proportion of doctoral science and engineering staff that are young (with seven or less years of academic experience) for 1982 and 1987.

Methodological Differences

The three primary differences between the Kuh-Radner and the NSF methodologies are (1) the way in which changes in enrollments (or baccalaureates) are projected, (2) the difference in emphasis between a set of projections for only two points in time (NSF) versus the projection of a time series, and, finally, (3) the degree of disaggregation of the NSF projections. Let us discuss these differences one at a time.

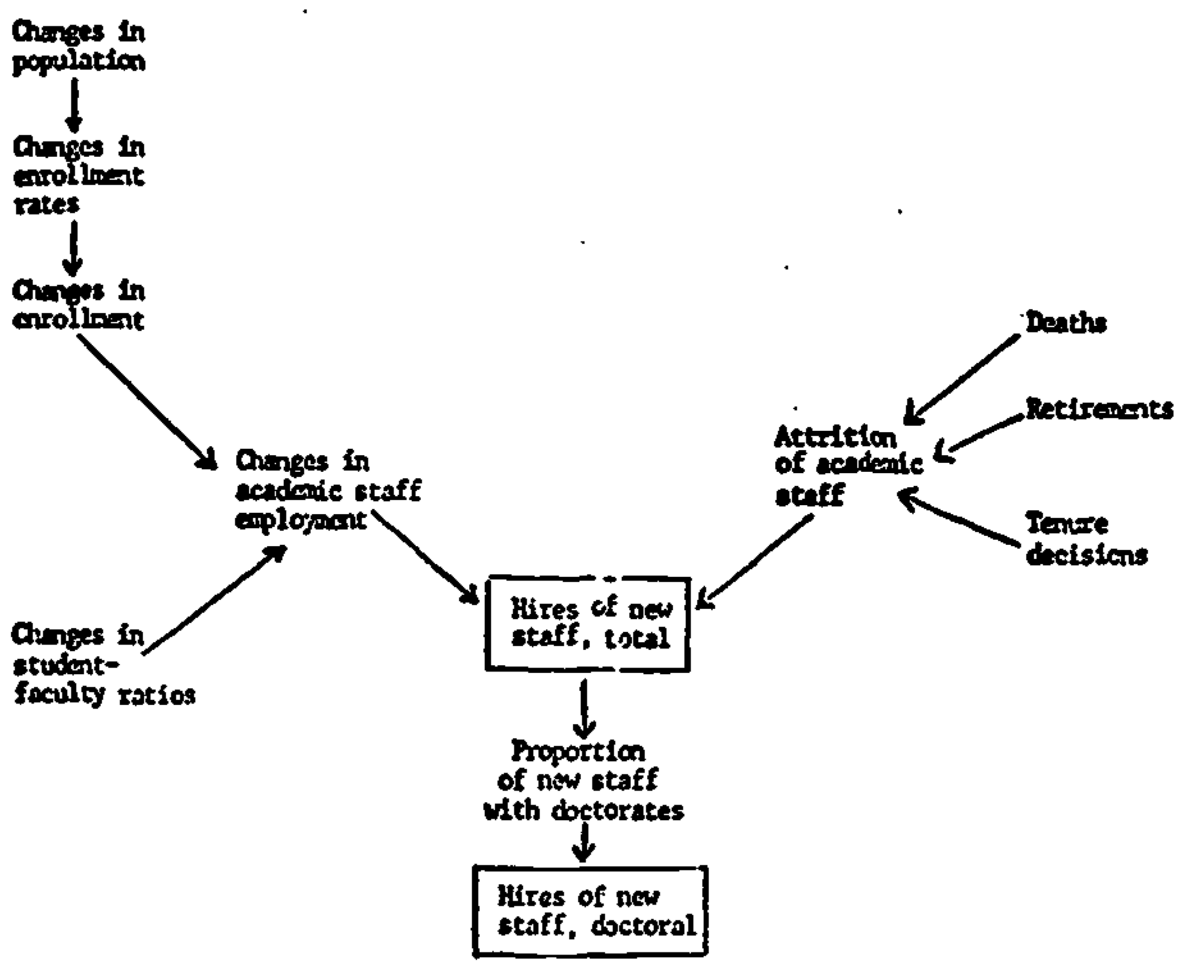
Enrollment Projections. Demography may not be everything, but it is an undisputed fact that the sizes of the 18-year-old cohorts, and even the 18-21 year-old cohorts, are going to decline between 1977 and 1982, and decline even more precipitiously between 1977 and 1987. The numbers are given in Table 3.1.

Participation rates of these or other cohorts would have to increase dramatically in order for baccalaureates to grow in a linear fashion. Thus we would think that any projective model should take demographic trends into account.

Point Predictions and Time Series Projections. The problem with the presentation of a time series of projections is that it gives a false impression of exactness. What is presented are annual point estimates while what is important for policy is the qualitative fact of fluctuations in demand and a general notion of the magnitude and duration of such fluctuations. The presentation of two point estimates does suffer less obviously from this problem, but the fact that demand fluctuates may be missed

FIGURE 3.2

PROJECTION MODELS FOR NEW DOCTORAL HIRES



Source: Division of Science Resources Studies, National Science Foundation

TABLE 3.1

PERCENTAGE CHANGE: COLLEGE AGE COHORTS

	Years	
Cohort	1977-82	1977-87
18 yr. old	- 3.7	- 16.0
18-21 yr. old	- 0.8	- 13.0

Source: National Center for Educati , Statistics, Projections of Education Statistics to 1986-87, Table B-2 entirely, depending on the choice of projection points. For example, the choice of 1982 and 1987, misses both the peak (in 1980) and the trough (in 1985) that are apparent in the Kuh-Radner model.

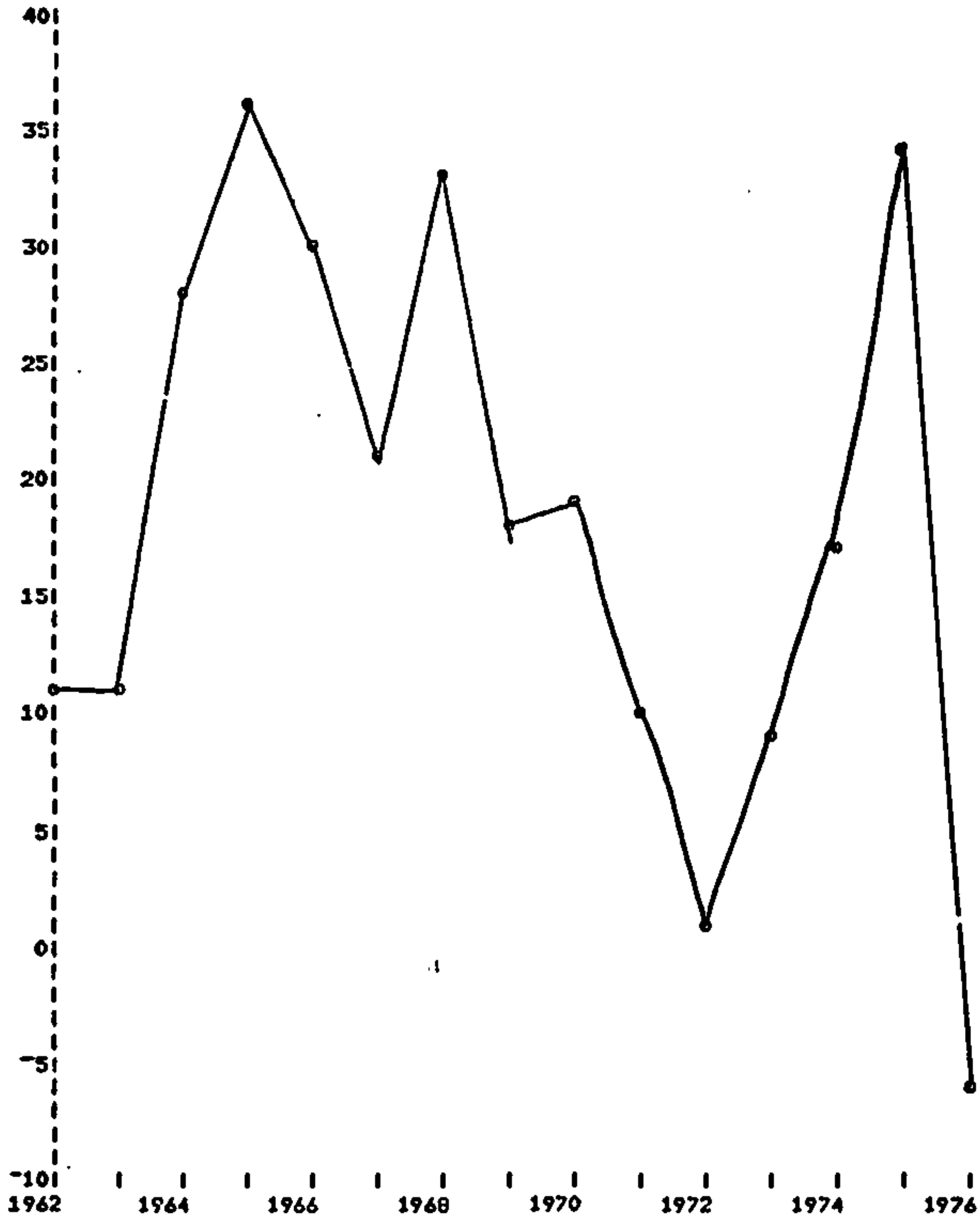
It may be argued that demand for new staff does not flucuate as violently as suggested by the Kuh-Radner results. However, the plot of first differences of number of FTE faculty from 1960 to 1976, presented in Figure 3.3, illustrates that even in a period of growth, fairly large fluctuations in full-time staff did occur.

The Degree of Disaggregation. The NSF projections are disaggregated by field of science and engineering. This disaggregation should provide a golden opportunity to take into account the varying age structures, field-by-field, of academic faculty. Kuh and Radner have some preliminary findings about mathematicians, for example, which indicate that because mathematics faculty are, on average, younger than faculty as a whole, and because there are more tenured young faculty, the young investigator problem will probably be worse for mathematicians than for faculty as a whole. The way in which the NSF projections use disaggregation, however, is to recognize that the size of the 1977 initial stock of academic staff differs by field. The age structure of faculty in each field is assumed to be the same as that for faculty as a whole in the 1973 American Council on Education (ACE) Survey. Field-specific differences are not incorporated in the projection technique.

Since we think the debate about the young investigator problem relates to the age-specific structure of knowledge, and since this structure probably varies by field, disaggregated estimates are important. They should, however, take into account field-specific age and mobility patterns.

Comparing the Models

In an attempt to make the two models comparable, we have taken three approaches. First, taking the NSF parameter values and baseline data, we have applied our simulation model requiring that the 1977 and 1987 values of academic doctoral demand be the same as those projected by the NSF. Fluctuations in demand, then, drive our dynamic model. The question that is



CHANGES IN FULL-TIME STAFF IN HIGHER EDUCATION 1962-1976 (In Thousands)

Source: National Center for Education Statistics, Projections of Education Statistics to 1986-87, Table 22 (earlier years from earlier volumes)

FIGURE 3.3

answered by this exercise is: what time pattern of new hiring is consistent with the NSF data and parameter values, but with the dynamics of the Kuh-Radner model? The second approach is to use the NSF data and parameters and to interpolate them linearly. Since, as far as we can tell, the baccalaureate series on which the NSF projections is based results from an approximately linear extrapolation of past data, this interpolative approach is entirely consistent with the NSF methodology. The third approach is to "scale down" our total faculty demand model to values consistent with the NSF 1977 baseline science and engineering stock, and then to run our model with our parameters. It should be noted that since we wrote "Preserving a Lost Generation. . .," we have obtained access to data from the Comprehensive Survey of Doctoral Scientists and Engineers of the Commission on Human Resources. The data base for our current projections differs somewhat from that in the circulated report. The qualitative results, however, are unchanged. A statistical summary of the projections from all three models is presented in Appendix I.

We find that unless the demand for academic places grows in a strongly counter-demographic manner, new hiring of doctoral science and engineering (S/E) faculty will decline markedly in the 1980's. All three models predict a decline of at least ten percentage points in the proportion of recent doctoral S/E faculty during the 1980's. These results are generated primarily by the demographic characteristics of the existing faculty stock and by the assumptions of each model concerning the pattern of enrollment-generated faculty demand.

II. The Models

The Kuh-Radner Model[1/]

We first describe the model used to make the projections that were presented in our paper, "Preserving a Lost Generation: Policies to Assure

[1/] The present model is an adaptation of one used previously for aggregate U.S. doctorate faculty projections. For a detailed description of that model, see L. Fernandez (1978). However, the parameters of that model have been revised to reflect data newly available to us from the Commission on Human Resources (CHR) of the National Research Council.

A Steady Flow of Young Scholars until the Year 2000." That demographic model follows each Ph.D. faculty cohort from the year of its entry into academia, until the year 2000. Formally, we use a Markov model with nonstationary transition probabilities. The state of an individual is characterized by "academic age" (number of years since the Ph.D. degree), biological age, and tenure status. Individuals may enter the system in any state, or leave from any state. (However, for all practical purposes, positive net flows into the system occur only at academic ages one and two.) The system is intended to represent the population of teaching faculty in four-year colleges and universities who have doctoral degrees.

The total stock of (doctoral) faculty in any one year is assumed to be given exogenously, and determined by academic demand. (See below for a discussion of the projections of stocks.) The number of individuals leaving the system in any one year (due to retirement and other attrition) is determined by the age and tenure-status distribution in that year. The number of new hires is the difference between the next year's total required stock (demand) and the remaining stock of individuals carried over from the current year.

The parameters of the model include the initial (1975) age and tenure-status distribution, and, for each calendar year:

(1) academic age-specific rates of "promotion", i.e., transition from non-tenure to tenure status;

(2) academic age and tenure-status specific rates of (net) attrition from the system other than attrition due to death and retirement;

(3) biological age-specific rates of death and retirement.

In addition, there is the series of demands for total faculty in each year, mentioned above. These various parameters are projected to change, over time, between the years 1975 and 2000, in response to the likely evolution of the market. However, the model incorporates no formal feedback mechanisms for the influence of market conditions on the model's parameters.

For the projections reported in "Preserving a Lost Generation....." we relied heavily on data from the American Council on Education and Carnegie Council faculty surveys (see Fernandez, 1978). Since distributing that report, we have revised many of the parameters of the model, using data recently available to us from the Commission on Human Resources of the National Research Council. (We have also made minor modifications in the computer program, eliminating some numerical approximations in the algorithm that are no longer necessary with our present computer.) The revised projections are presented in the Appendix to this paper. They do not differ substantially from the original projections, nor do they lead to any substantially different policy conclusions.

For the remainder of this paper, we shall refer to the revised model as the "CHR-data-based doctoral model." We shall first describe the data and assumptions of the CHR-data-based doctoral model, and then compare the model with what we understand to be the method that the NSF has used to project the 1986-87 "Recent Faculty Ratio." Finally, we shall explain how we have adapted the CHR-data-based doctoral model to incorporate the assumptions and data used in the NSF projections. In this way, we hope to elucidate to what extent the differences between the two sets of projections are due to differences in methodology, and to what extent they are due to differences in the data and underlying parameters.

Our estimates of the initial age distribution and number of doctorate faculty in 1975 are based upon data from the 1975 Survey of Doctorate Recipients, which is conducted by the Commission on Human Resources for the NSF (National Research Council, 1976).

Academic age-specific promotion rates have been estimated from survey data supplied by the Commission on Human Resources, using a conditional logit method of estimation (Kuh and Radner, 1977; Kuh, 1977). This method enables us to estimate how the age-specific promotion rates have changed during past years, and to see how these changes have correlated with past changes in market conditions. Because of limitations of the data, similar but cruder methods have been used to estimate age and tenure-status specific attrition rates. Retirement rates have been projected from figures for U.S. faculty as a whole developed elsewhere,[2] and are intended to incorporate a moderate response to the extension of the mandatory retirement age that (under present legislation) will begin in 1981. The projected evolution of the above parameters is shown in the Appendix to this paper.

In the CHR-data-based doctoral model, we have retained the projections of total demand for (doctorate) faculty that were developed elsewhere.[2]

The NSF Model[3]

The NSF projection of the ratio of "recent" doctoral staff to total doctoral staff in 1987 is designed to estimate this ratio without explicitly following the year-to-year details of the experience of the different cohorts. ("Recent" staff are defined as those who have had their doctorates seven years or less.) Nevertheless, the assumptions that underlie the NSF projections can be understood, we believe, within the framework of the doctoral model based on ChR data.

First, the initial stages of the NSF calculation deal with the full-time staff, both doctoral and non-doctoral, who are primarily engaged in teaching, in all institutions of higher education, including two-year colleges. The staff considered are limited to the five science and engineering (S/E) fields, which are first considered separately. For each S/E field except Social Science, the faculty stock in the projection year (e.g., 1987) is predicted from regressions that were estimated from historical data on academic staff and S/E baccalaureates. The stock of social science faculty is projected to remain at its 1977 level. The numbers of baccalaureate degrees in each S/E field are assumed to increase or decrease according to present trends.

---

[2] See L. Fernandez, (1978). These projections are based upon projections of student enrollments, together with a constant faculty-student ratio.

[3] The following material represents our understanding of the NSF methodology. Charles Falk and Larry Lacy kindly provided the information on which our account is based, but they are in no way responsible for errors in it.

Death rates are obtained from the Teachers Insurance and Annuity (TIAA) experience. All faculty are assumed to retire at age 66.

All promotions from non-tenure to tenure status occur at academic age seven, and only at that age. One-half of all non-tenured faculty eventually receive tenure. Tenured faculty experience no net attrition from the system, except for death and retirement. Attrition of non-tenured faculty occurs only after seven years, at which time all non-t nured faculty who have not been promoted to tenure leave the system. All (net) new hires into the system in any one year have academic age one.

The biological age distribution of S/E faculty in 1977 is estimated from the 1973 ACE faculty survey. Data from an NSF survey (1974) provide a basis for estimating the fraction of S/E faculty who have tenure in 1977.

Even with the above assumptions about the time-structure of the rates of promotion, retirement, and other attrition, one cannot project the total new faculty hires between 1977 and 1987 without making some assumption about the time-path of changes in the total faculty stock. For example, to consider two extreme cases; suppose first that the entire change, say C, in the faculty stock occurred at the beginning of the period. This change would generate C new hires at the beginning of the period; after seven years, half of these would leave the system for lack of promotion, and C/2 more new hires would enter the system to replace them. On the other hand, if the entire change in the stock occurred in the last year of the period, then there would be no attrition from this group by the end of the period, and the total new hires generated by changes in the stock would be C. (In addition, of course, there would be new hires generated by death, retirement, and attrition from the faculty already present in 1977.) As far as we understand the NSF method, it is equivalent to the assumption that the annual changes in the stock of faculty, as well as the annual replacements generated by death, retirement, and other attrition from the 1977 stock, are all constant over time. We shall call this "Assumption A."

To project the number of new faculty hires <u>with the doctorate</u>, during the period 1977-87, the NSF uses estimates of the proportion of faculty hired in recent years who have the doctorate, and assumes that this proportion will be ten percent higher during the projection period. This analysis (the details of which we have not seen) yields a projection that approximately 84 percent of new faculty hired during the period 1977-87 will have a doctoral degree.

From an estimate of the age and tenure distribution of the doctoral faculty stock in 1977, together with the above assumptions on the various rates, one can also project the number of doctoral S/E faculty in 1977 who survive until 1987; call these the "survivors." In 1987, all of these survivors have academic age greater than seven. The total number of doctoral S/E faculty in 1987 is, of course, the sum of the number of survivors and the number of surviving new hires. From "Assumption A" above, one can also calculate the number of surviving new hires who have academic age seven or less; the ratio of this number to the total stock is the "Recent Faculty Ratio."

The Method of Comparison

As we have presented it, the NSF model is conceptually similar to the Kuh-Radner model, but incorporates a number of simplifying assumptions about promotion, retirement, and attrition rates, and about the rate of flow of new hires into the system (Assumption A) that enable one to use a simpler algorithm for projecting total new hires of doctoral S/E faculty during the period 1977-87, and the "recent faculty ratio" in 1987. The NSF model also makes different assumptions about the numerical magnitudes of various parameters, and about the projected stock of faculty. It should also be kept in mind that the NSF model (for the projection of the "recent faculty ratio") is concerned with doctoral S/E faculty in all sectors of higher education, whereas the Kuh-Radner model is concerned with doctoral faculty in all fields, but only in four-year colleges and universities.

Since the two have the same conceptual basis, but the Kuh-Radner model allows more flexible assumptions, it is relatively straightforward to build the NSF assumptions into the Kuh-Radner model. We have done this in three stages, in order to explore the sources of the differences in the projections. First, we have retained the parameters of the doctoral model based on CHR data, except that we have scaled the projection of the time series of faculty stocks so that the 1977 faculty stock is equal to the figure used by the NSF model for all S/E faculty (both doctoral and non-doctoral) in 1977; we call these the CHR data-based projections scaled to NSF's 1977 S/E faculty stock.

Second, we have taken the total S/E faculty stocks in 1977 and 1987 to be the same as in the NSF model, but have assumed that the entire series of faculty stocks will fluctuate through time with the same pattern as in the CHR-data-based doctoral model. We have also used all of the other assumptions of the NSF model about promotion, death, retirement, and attrition, but not Assumption A. (The year-by-year calculation of the Kuh-Radner model eliminates the need to use Assumption A.) Unfortunately, in the time available to us we were unable to obtain initial age and tenure distributions comparable to those implicit in the NSF model, in the detail needed to implement the Kuh-Radner model, so we retained the CHR distribution.[4/] We call these the projections with NSF parameters and constrained demographic demand, or "NSF-1."

Third, we modify the NSF-1 model by fixing the projected faculty stocks at 1977, 1982, and 1987 at levels used by NSF, and interpolating linearly in between. We call these the projections based on NSF parameters and two-segment linear demand, or "NSF-2."

Each of the above three models leads to year-by-year projections of the age and tenure structure of faculty stocks, of new hires, deaths and retirements, etc. (Recall that the Kuh-Radner model takes account of both biological and academic ages.) To obtain a series of new doctoral hires from any model, we adopt the NSF assumption and multiply the corresponding series of total new hires by .837, which is the incremental doctoral faculty ratio.

For each of the above three models one easily obtains a series of "recent faculty ratios" for total faculty. In order to obtain corresponding estimates of "recent <u>doctoral</u> faculty" ratios, one should, in principle, keep separate track of the demographic structures of doctoral and non-doctoral faculty. With the time and data available to us, we were not able to do the necessary calculations, although they would be relatively straightforward. Instead, we divided the 1987 faculty stock into three groups;

[4/] Experiments with the CHR-data-based doctoral model indicate that moving from an initial distribution based on the ACE faculty survey to one based on CHR data produces only small changes in the projections.

(1) "recent" new hires since 1977, (2) non-recent new hires since 1977, and (3) survivors from 1977 (all non-recent, by definition), and applied the corresponding doctoral fractions of .837, .837, and .675, respectively. Analogous calculations were done for the other years.

Young Research Faculty

It can be argued that if one is interested in the health of academic research, then one should restrict one's attention to the numbers of young faculty in the academic institutions where the bulk of research is done. Many of these are prestigious orivate colleges and universities with relatively stable enrollments and faculty sizes, where new hires are largely insulated from the demographic forces affecting nationwide college enrollments. Attrition rates for this sector may also be considerably higher than for academia as a whole, since faculty at research institutions can leave for jobs elsewhere in academia, as well as outside academia. In a study of mathematicians (Kuh and Radner, 1980), we have assumed that attrition rates for research universities are three times attrition rates for academia as a whole. The result is a fall in the young faculty ratio that is one percentage point less than that for academia as a whole between 1976 and 1985.

III. Results

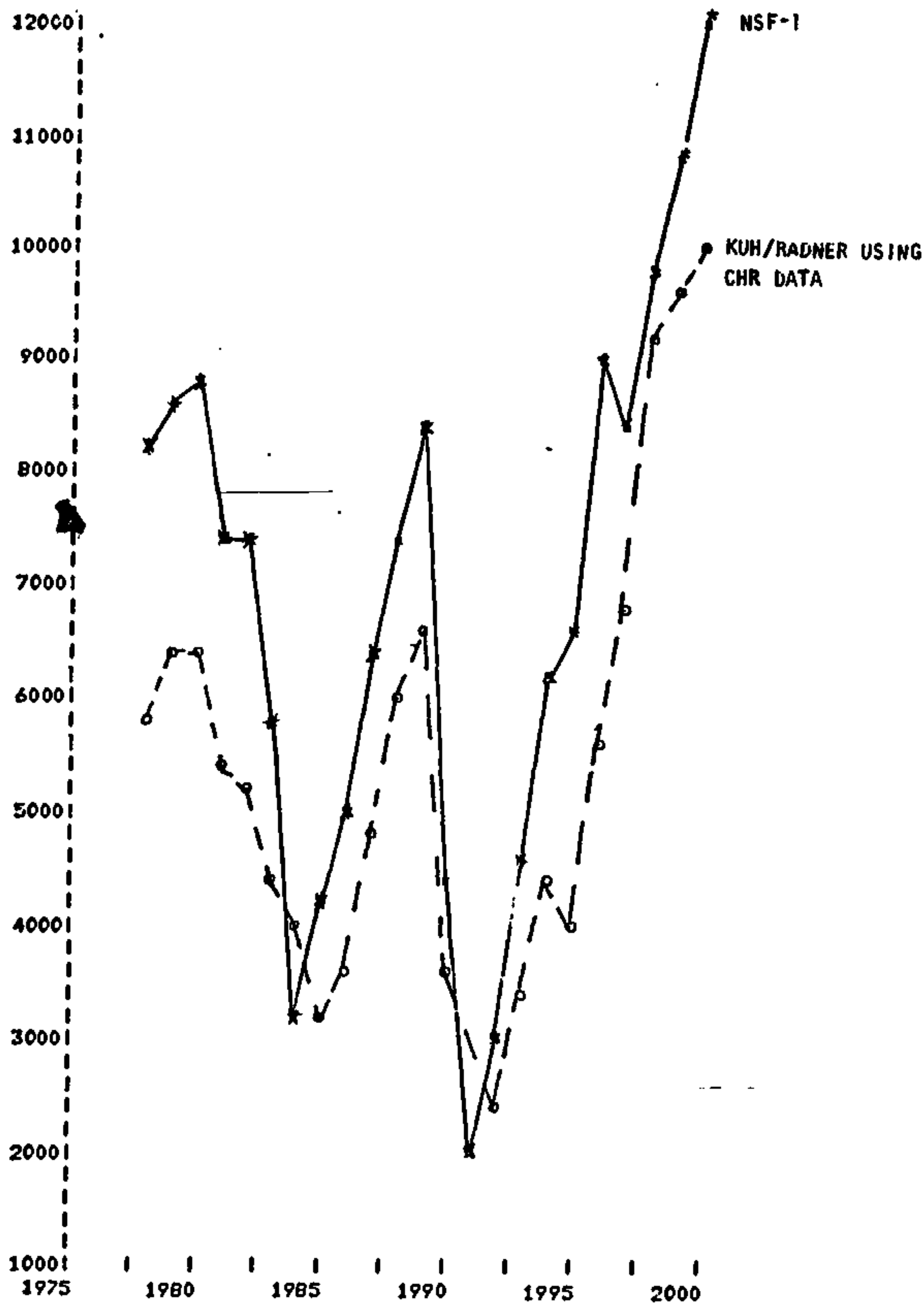
The two types of results of central relevance to the young investigator problem are: 1) new hiring, and 2) the share of faculty with seven or less years of academic experience. Table 3.2 presents the values from each of the three models for new hires and graphs of these values are presented in Figures 3.4 and 3.5. Table 3.3 presents an index of these values relative to the base year of 1977. Graphs corresponding to the tables follow (Figures 3.6 and 3.7).

Looking first at new hiring, the projections from the NSF model with fluctuating demand (NSF-1) start out higher than either of the other models, and for most years give greater levels of new hiring than the CHR-data-based doctoral model. The shape of fluctuations, however, is very similar, as would be expected. The linear extrapolation model with NSF parameters (NSF-2)

TABLE 3.2

PROJECTED DOCTORATE NEW HIRES IN S/E FACULTY

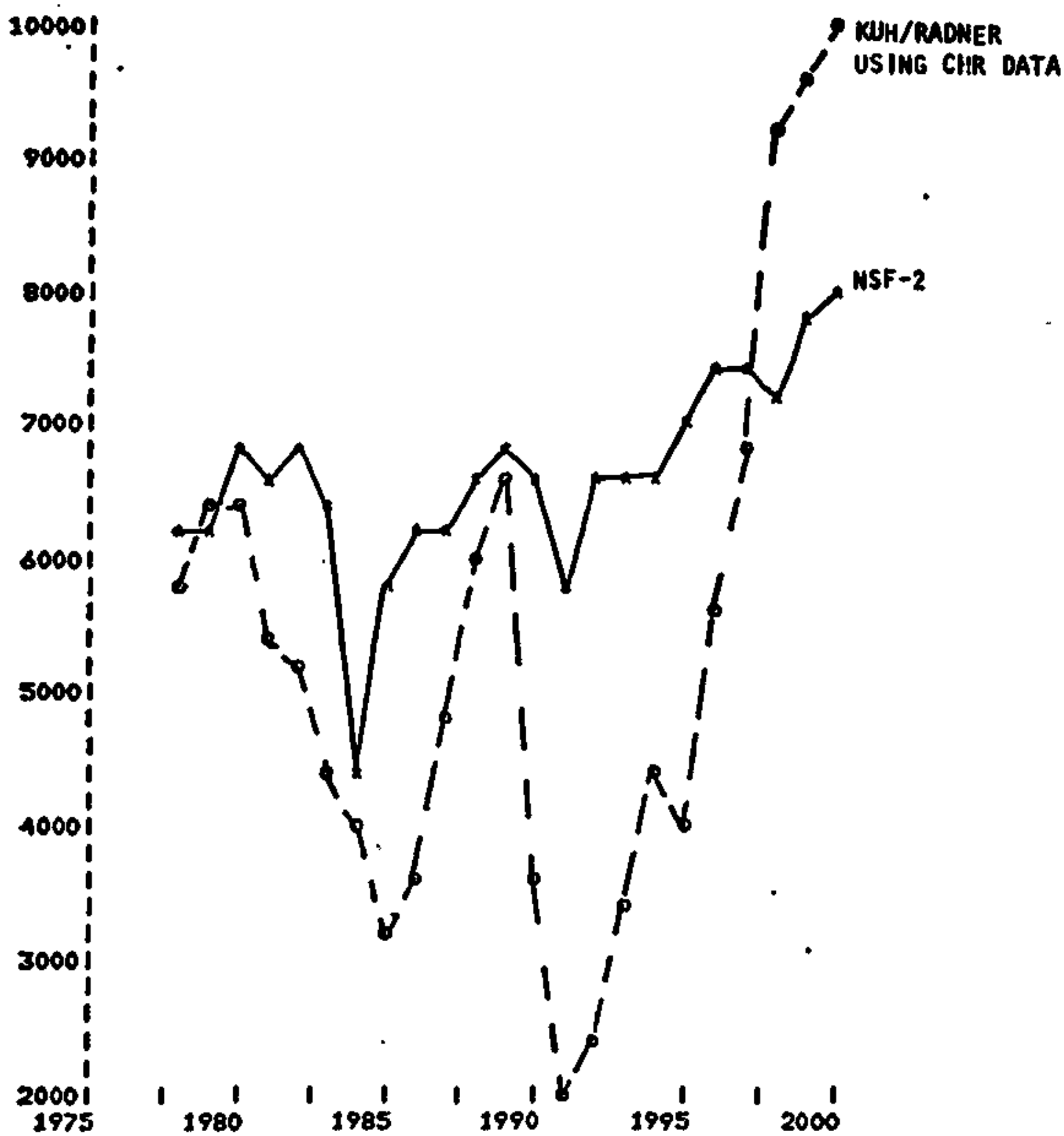
Year	CHR DATA-BASED	NSF-1	NSF-2
1978	5860	8167	6199
1979	6404	8606	6264
1980	6393	8716	6712
1981	5372	7477	6603
1982	5259	7301	6860
1983	4362	5807	6398
1984	4035	3167	4414
1985	3184	4117	5716
1986	3516	5017	6188
1987	4794	6460	6292
1988	5964	7401	6600
1989	6603	8353	6833
1990	3662	4464	6555
1991	2025	1987	5818
1992	2342	3060	6583
1993	3485	4554	6627
1994	4483	6295	6644
1995	4006	6662	7092
1996	5504	8969	7436
1997	6827	8377	7324
1998	9148	9816	7199
1999	9516	10787	7744
2000	9938	11921	7906



PROJECTED DOCTORATE NEW HIRES

– – – – O KUH/RADNER USING CHR DATA

———— X NSF-1



PROJECTED DOCTORATE NEW HIRES

- - - - O KUH/RADNER USING CHR DATA

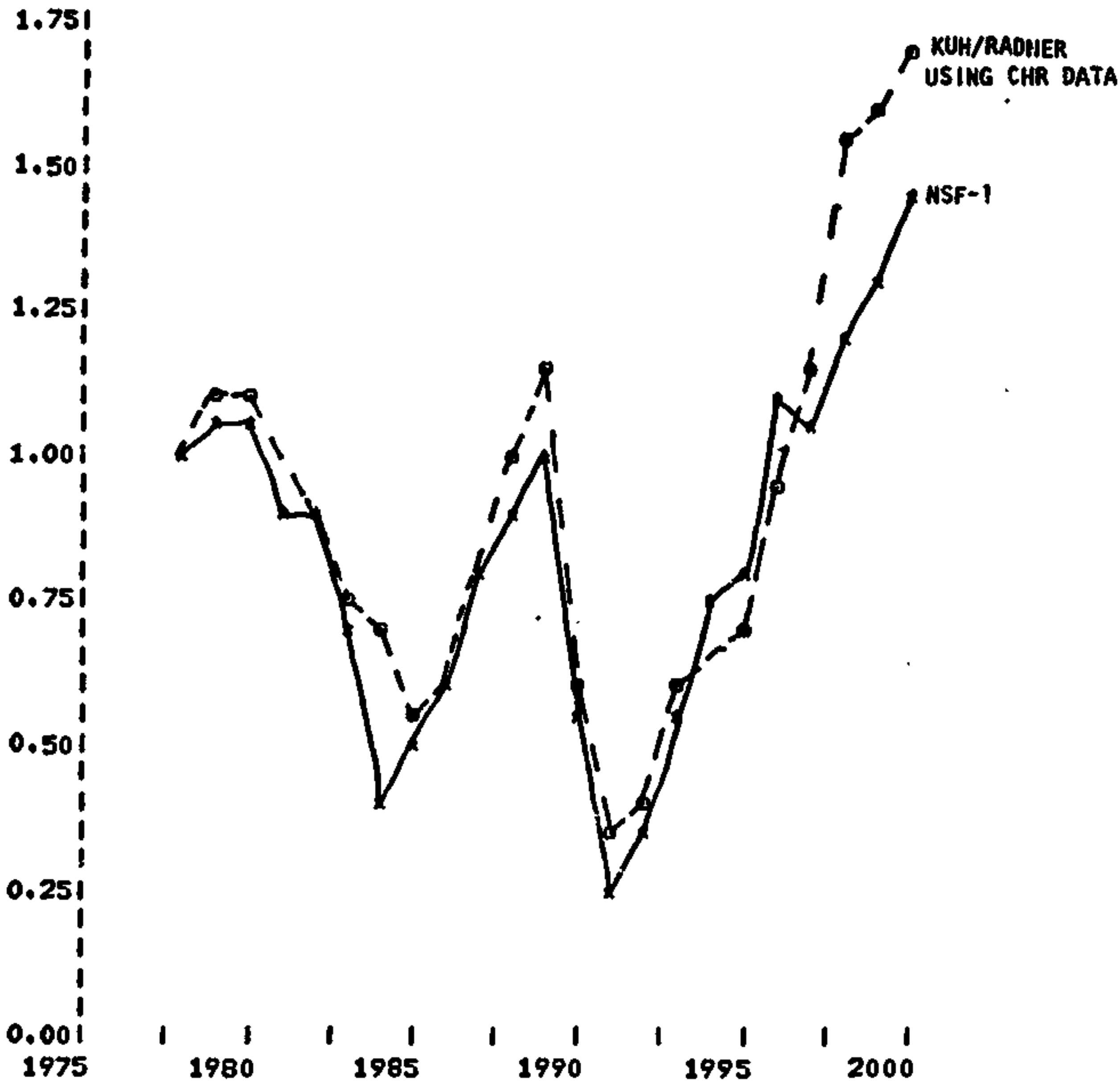
——— x NSF-2

FIGURE 3.5

TABLE 3.3

RELATIVE PROJECTED DOCTORATE NEW HIRES

Year	CHR OATA-BASEO	NSF-1	NSF-2
1978	1	1	1
1979	1.0928	1.0537	1.0105
1980	1.091	1.0672	1.0828
1981	0.9167	0.9155	1.0651
1982	0.8974	0.894	1.1065
1983	0.7444	0.711	1.032
1984	0.6886	0.3877	0.712
1985	0.5433	0.504	0.9221
1986	0.6	0.6143	0.9981
1987	0.8181	0.791	1.0149
1988	1.0178	0.9062	1.0647
1989	1.1268	1.0227	1.1023
1990	0.6249	0.5466	1.0574
1991	0.3456	0.2433	0.9386
1992	0.3996	0.3747	1.0619
1993	0.5948	0.5575	1.069
1994	0.7651	0.7707	1.0718
1995	0.6836	0.8157	1.1441
1996	0.9393	1.0981	1.1996
1997	1.165	1.0257	1.1814
1998	1.5612	1.2019	1.1614
1999	1.6239	1.3208	1.2492
2000	1.6959	1.4596	1.2754

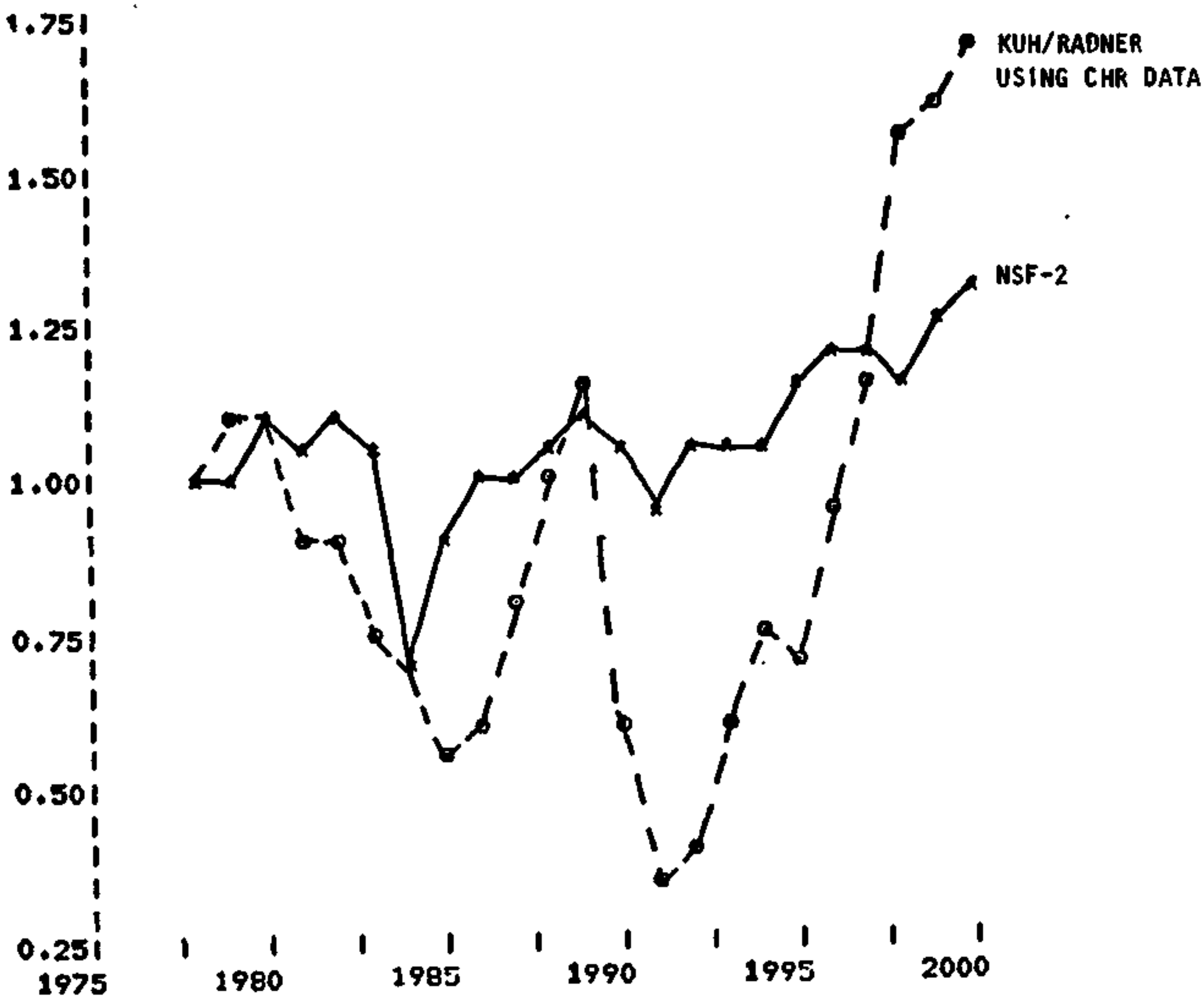


RELATIVE PROJECTED DOCTORATE NEW HIRES

- - - - O KUH/RADNER USING CHR DATA

——— x NSF-1

FIGURE 3.6



RELATIVE PROJECTED DOCTORATE NEW HIRES

---- 0 KUH/RADNER USING CHR DATA

——— x NSF-2

FIGURE 3.7

does not yield the deep troughs predicted in the 1980's by the other two models. The dip in 1984 results from imperfect matching of CHR data and the linear demand model and probably overstates the decline. In the 1990's, both NSF-1 and the CHR-data-based doctoral model give greater levels of new hiring than NSF-2. In some sense, NSF-2 gives the "best" outlook for new hiring over the period, since it exhibits neither severe fluctuations nor very low levels of demand. The main problem is the realism of the assumption that enrollment demand can grow in a linear manner in the face of declining cohort size.

Calculation of <u>relative</u> new hires effectively scales the results so that differences in assumptions about initial values loom less prominently. In general, NSF-1 yields slightly greater fluctuations in new hiring than the CHR data-based model, the greater decline in new hiring in the 1980's being to 39 percent of 1978 levels and in the 1990's to 24 percent of 1978 levels. If we look at the point estimates for 1982 and 1987, however, we see that the relative values of new hires are very similar for those years. The principal difference then, between the new hire predictions from the two models is attributable to the different <u>levels</u> of new hiring. This difference comes from the NSF assumption that attrition rates are zero for the first six academic ages, and that thereafter one-half of the non-tenured faculty are promoted and one-half leave. There are no non-tenured faculty of academic age greater than seven. The CHR-data-based doctoral model, on the other hand, spreads attrition more smoothly over academic ages, although our gross attrition rates are very similar to the NSF.

The importance of the differences in assumptions about attrition and the age structure is also evident in the differences in the projected fraction of faculty with less than eight years of academic teaching experience. These results are shown in Tables 3.4, 3.5, and 3.6 for CHR-data-based, NSF-1, and NSF-2 and graphs of these values are shown in Figures 3.8 and 3.9. The CHR-data-based results are lower than the results from either of the NSF models, in absolute value. The relative values however, are quite similar, and all values, even those from the linear demand model, show a fall of over 30 percent in the share of young faculty. The young investigator problem seems evident. A complete description of the demographic evolution of the stock of faculty from 1977 to 2000 from each of the models may be found in Appendix 1.

TABLE 3.4

PROJECTIONS OF RECENT DOCTORAL FACULTY

KUH/RADNER USING CHR DATA

	Recent Doctoral Faculty			Relative Recent Doctoral Faculty	
YEAR	YOUNG PH.D.'s	TOTAL PH.D.'s	RATIO	YOUNG PH.D.'s	RATIO
1977	32219	104376	0.309	1	1
1978	31266	107361	0.291	0.97	0.943
1979	31962	110693	0.289	0.992	0.935
1980	32539	113683	0.286	1.01	0.927
1981	32507	115508	0.281	1.009	0.912
1982	34274	116911	0.293	1.064	0.95
1983	33459	116986	0.286	1.039	0.927
1984	32287	116375	0.277	1.002	0.899
1985	29271	114476	0.256	0.909	0.828
1986	26515	112812	0.235	0.823	0.761
1987	25463	112591	0.226	0.79	0.733
1988	26448	113536	0.233	0.821	0.755
1989	28288	115343	0.245	0.878	0.795
1990	27803	114253	0.243	0.863	0.786
1991	26035	111849	0.233	0.808	0.754
1992	25241	109935	0.23	0.783	0.744
1993	25357	109207	0.232	0.787	0.752
1994	25511	109484	0.233	0.792	0.755
1995	24272	109399	0.222	0.753	0.719
1996	23972	110790	0.216	0.744	0.701
1997	27316	113392	0.241	0.848	0.78
1998	34214	118187	0.289	1.062	0.938
1999	41031	123191	0.333	1.274	1.079
2000	47127	128388	0.367	1.463	1.189

TABLE 3.5

PROJECTIONS OF RECENT DOCTORAL FACULTY

NSF-1

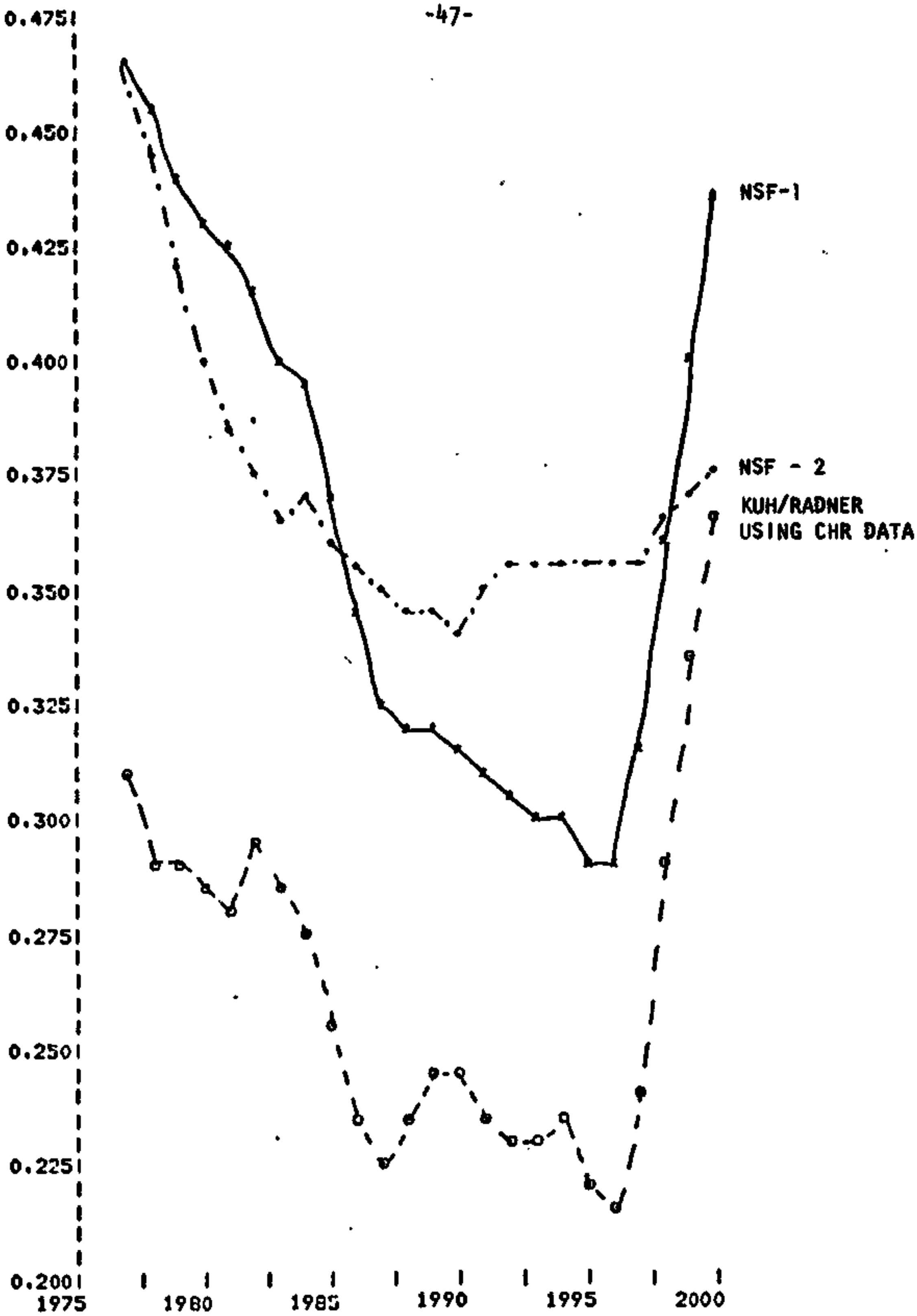
	Recent Doctoral Faculty			Relative Recent Doctoral Faculty	
YEAR	YOUNG PH.D.'s	TOTAL PH.D.'s	RATIO	YOUNG PH.D.'s	RATIO
1977	48356	104376	0.463	1	1
1978	49053	108337	0.453	1.014	0.977
1979	49802	112682	0.442	1.03	0.954
1980	50251	116772	0.43	1.039	0.929
1981	50663	119707	0.423	1.048	0.914
1982	50577	122256	0.414	1.046	0.893
1983	49316	123382	0.4	1.02	0.863
1984	49058	123465	0.397	1.015	0.858
1985	45014	121876	0.369	0.931	0.797
1986	41441	120616	0.344	0.857	0.742
1987	39206	120841	0.324	0.811	0.7
1988	39145	122327	0.32	0.81	0.691
1989	40212	124765	0.322	0.832	0.696
1990	38872	124091	0.313	0.804	0.676
1991	37673	122046	0.309	0.779	0.666
1992	36605	120506	0.304	0.757	0.656
1993	36137	120163	0.301	0.747	0.649
1994	35979	120870	0.298	0.744	0.643
1995	35259	121236	0.291	0.729	0.626
1996	35904	123247	0.291	0.742	0.629
1997	39814	126565	0.315	0.823	0.679
1998	47615	132342	0.36	0.985	0.777
1999	55313	138410	0.4	1.144	0.863
2000	62655	144741	0.433	1.296	0.934

TABLE 3.6

PROJECTIONS OF RECENT DOCTORAL FACULTY

NSF-2

	Recent Doctoral Faculty			Relative Recent Doctoral Faculty	
YEAR	YOUNG PH.D.'s	TOTAL PH.D.'s	RATIO	YOUNG PH.D.'s	RATIO
1977	48356	104376	0.46[illegible]	1	1
1978	47084	106369	0.443	0.974	0.955
1979	45493	108373	0.42	0.941	0.906
1980	43942	110463	0.398	0.909	0.859
1981	43467	112531	0.386	0.899	0.834
1982	42967	114647	0.375	0.889	0.809
1983	42306	116372	0.364	0.875	0.785
1984	43305	117712	0.368	0.896	0.794
1985	42821	118707	0.361	0.886	0.779
1986	42744	119786	0.357	0.884	0.77
1987	42328	120841	0.35	0.875	0.756
1988	42330	121964	0.347	0.875	0.749
1989	42311	123106	0.344	0.875	0.742
1990	42471	124237	0.342	0.878	0.738
1991	43863	125412	0.35	0.907	0.755
1992	44725	126608	0.353	0.925	0.762
1993	45163	127764	0.353	0.934	0.763
1994	45513	128909	0.353	0.941	0.762
1995	46006	130107	0.354	0.951	0.763
1996	46612	131345	0.355	0.964	0.766
1997	47380	132581	0.357	0.98	0.771
1998	48754	133857	0.364	1.008	0.786
1999	49911	135156	0.369	1.032	0.797
2000	51187	136475	0.375	1.059	0.81

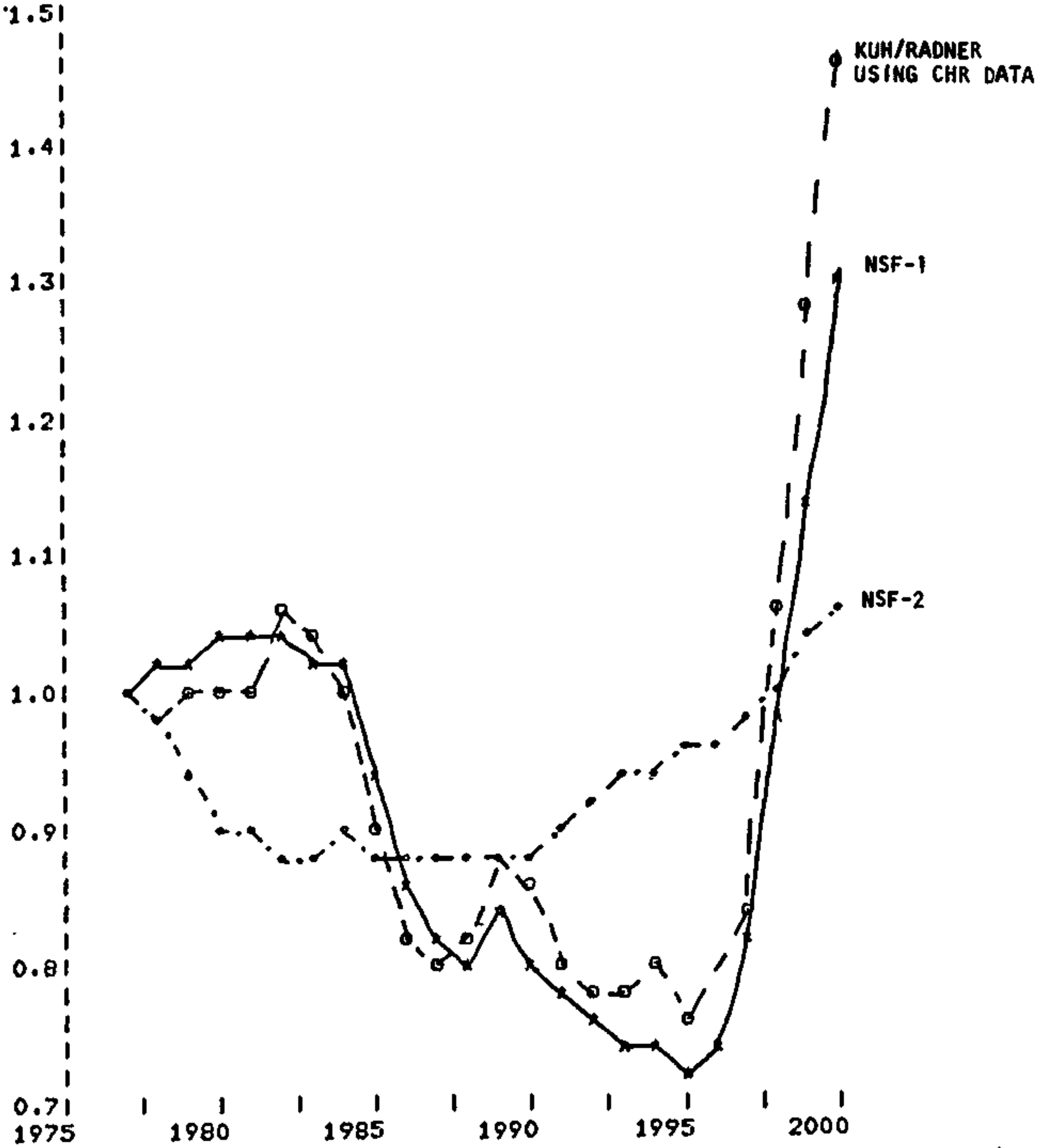


FRACTION OF DOCTORAL FACULTY WITH LESS THAN EIGHT YEARS OF EXPERIENCE

- - - - O KUH/RADNER USING CHR DATA

——— x NSF-1

-.-. . NSF-2



NUMBER OF "YOUNG" DOCTORATE FACULTY RELATIVE TO BASE YEAR

- - - - O KUH/RADNER USING CHR DATA

——— x NSF-1

-. -. • NSF-2

FIGURE 3.9

A somewhat dramatic presentation of the effect of the demographic state of the system on the careers of young investigators is presented in Tables 3.7, 3.8, and 3.9, which, for each year following the Ph.D., present the cumulative probabilities of promotion, attrition, or staying derived from the Kuh-Radner model for the Ph.D. cohorts of 1977, 1982, and 1987. The following two graphs give a comparative picture of the experience of each cohort (Figures 3.10 and 3.11). The 1977 cohort has the greatest probability of remaining academically employed and achieving tenure. The 1982 cohort has the worst experience, while the 1987 cohort enters in time to be promoted when the Census-projected boom in the mid-1990's comes along. This difference in cohort experiences is perhaps best illustrated by the probability of achieving promotion seven years or less after receipt of the Ph.D. These probabilities are .41 for the 1977 cohort, .29 for the 1982 cohort, and .29 for the 1987 cohort. The 1987 cohort, however, has a corresponding probability of .44 ten years after the Ph.D., while for the 1982 cohort this probability is only .40.

Two conclusions seem warranted on the basis of all three models. First, unless the stock of faculty grows in a strongly counter-demographic manner, new hiring of science and engineering faculty will decline markedly in the 1980's and the trough will be deeper to the extent that the stock of faculty follows the demographic changes in the college-age population. Second, the share of faculty with less than eight years experience will decline by at least ten percentage points between now and the mid-1980's. These results may be modified somewhat by smoothing (see Appendix I) but in the absence of intervention, this change is in the demographic cards.

IV. Conclusions

What have we learned from these alternative simulations of academic demand over the next 23 years? Our feeling is that both the NSF and our model have their merits and that a better modelling methodology would incorporate the desirable aspects of both. For policy purposes a dynamic

TABLE 3.7

PROJECTED EXPERIENCE FOR 1977 COHORT OF NEW PH.D. FACULTY*

Cumulative Probabilities for Those

Staying	Promoted	Leaving	Year	Academic Age
.942	.0319	.0261	1978	1
.3896	.0553	.0551	1979	2
.8183	.0961	.0856	1980	3
.7185	.1655	.116	1981	4
.60	.2558	.1442	1982	5
.4238	.3432	.233	1983	6
.2892	.4103	.3004	1984	7
.1973	.4515	.3512	1985	8
.1376	.4758	.3867	1986	9
.1101	.4882	.4017	1987	10
.0881	.4993	.4126	1988	11
.0702	.5094	.4204	1989	12
.0563	.5178	.4259	1990	13
.0458	.5243	.4299	1991	14
.039	.5282	.4328	1992	15
.0339	.5311	.435	1993	16
.0316	.5333	.435	1994	17
.0298	.5352	.435	1995	18
.0277	.5373	.435	1996	19
.0252	.5398	.435	1997	20
.0234	.5416	.435	1998	21
.0221	.5429	.435	1999	22
.0208	.5441	.435	2000	23

Median Years of Experience as Non-Tenured Faculty:

--Of those who leave academia is: 6.296
--Of those who are given tenure is: 6.251
--Of those in either group above is: 6.199

With 2.083 percent of the cohort still in non-tenured faculty positions in Year 2000 with 23 years of experience

Median Experience of the Full Cohort Will Lie between:

--6.619 and 7.078 years

*Based on Kuh/Radner model using CHR data.

TABLE 3.8

PROJECTED EXPERIENCE FOR 1982 COHORT OF NEW PH.D. FACULTY*

Cumulative Probabilities for Those

Staying	Promoted	Leaving	Year	Academic Age
.9253	.0266	.0482	1983	1
.8572	.0456	.0971	1984	2
.781	.0733	.1456	1985	3
.6955	.1156	.1889	1986	4
.6117	.1645	.2238	1987	5
.457	.2234	.3195	1988	6
.3321	.2863	.3816	1989	7
.2385	.3405	.421	1990	8
.1739	.38	.4461	1991	9
.1449	.3981	.457	1992	10
.1243	.4108	.4649	1993	11
.1079	.4215	.4706	1994	12
.0938	.4317	.4745	1995	13
.0815	.4406	.4779	1996	14
.0705	.4487	.4809	1997	15
.0602	.4564	.4834	1998	16
.0548	.4619	.4834	1999	17
.0512	.4655	.4834	2000	18

Median Years of Experience as Non-Tenured Faculty:

--Of those who leave academia is: 5.454
--Of those who are given tenure is: 6.989
--Of those in either group above is: 6.031

With 5.116 percent of the cohort still in non-tenured faculty positions in Year 2000 with 18 years of experience.

Median Experience of the Full Cohort Will Lie Between:

--6.810 and 8.191 years

*Based on Kuh/Radner model using CHR data.

TABLE 3.9

PROJECTED EXPERIENCE FOR 1987 COHORT OF NEW PH.D. FACULTY*

Cumulative Probabilities for Those				
Staying	Promoted	Leaving	Year	Academic Age
.9346	.0168	.0487	1988	1
.8768	.0332	.09	1989	2
.8096	.0663	.1242	1990	3
.7219	.1269	.1511	1991	4
.6426	.1854	.172	1992	5
.533	.2394	.2276	1993	6
.44	.2948	.2653	1994	7
.3586	.352	.2894	1995	8
.2899	.4012	.3089	1996	9
.2446	.4363	.319	1997	10
.2047	.4677	.3276	1998	11
.1737	.4915	.3348	1999	12
.1488	.5101	.341	2000	13

Median Years of Experience as Non-Tenured Faculty:

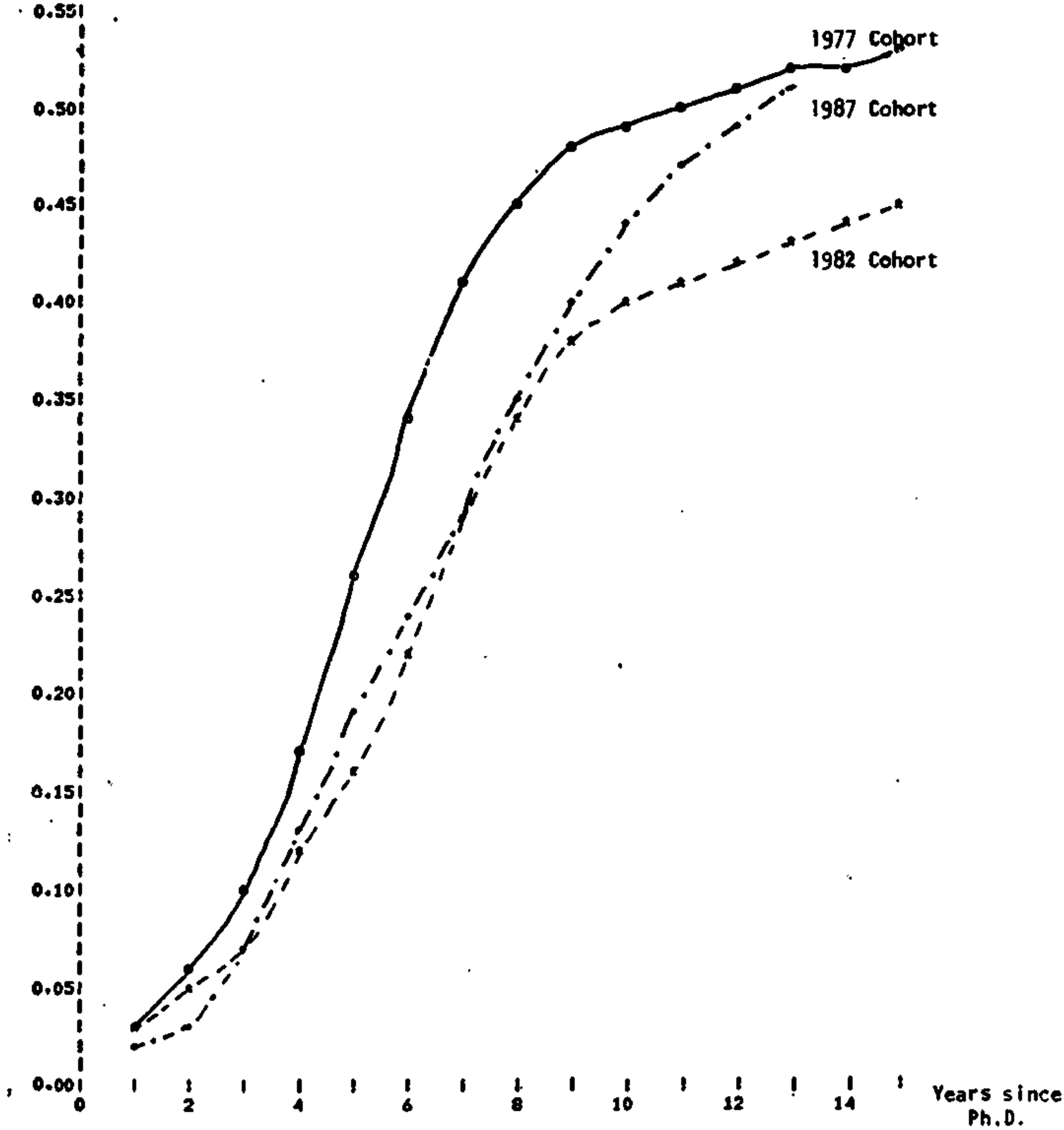
--Of those who leave academia is: 5.204
--Of those who are given tenure is: 6.901
--Of those in either group above is: 5.605

With 14.884 percent of the cohort still in non-tenured faculty positions in Year 2000 with 13 years of experience

Median Experience of the Full Cohort Will Lie Between:

--7.230 and 11.993 years

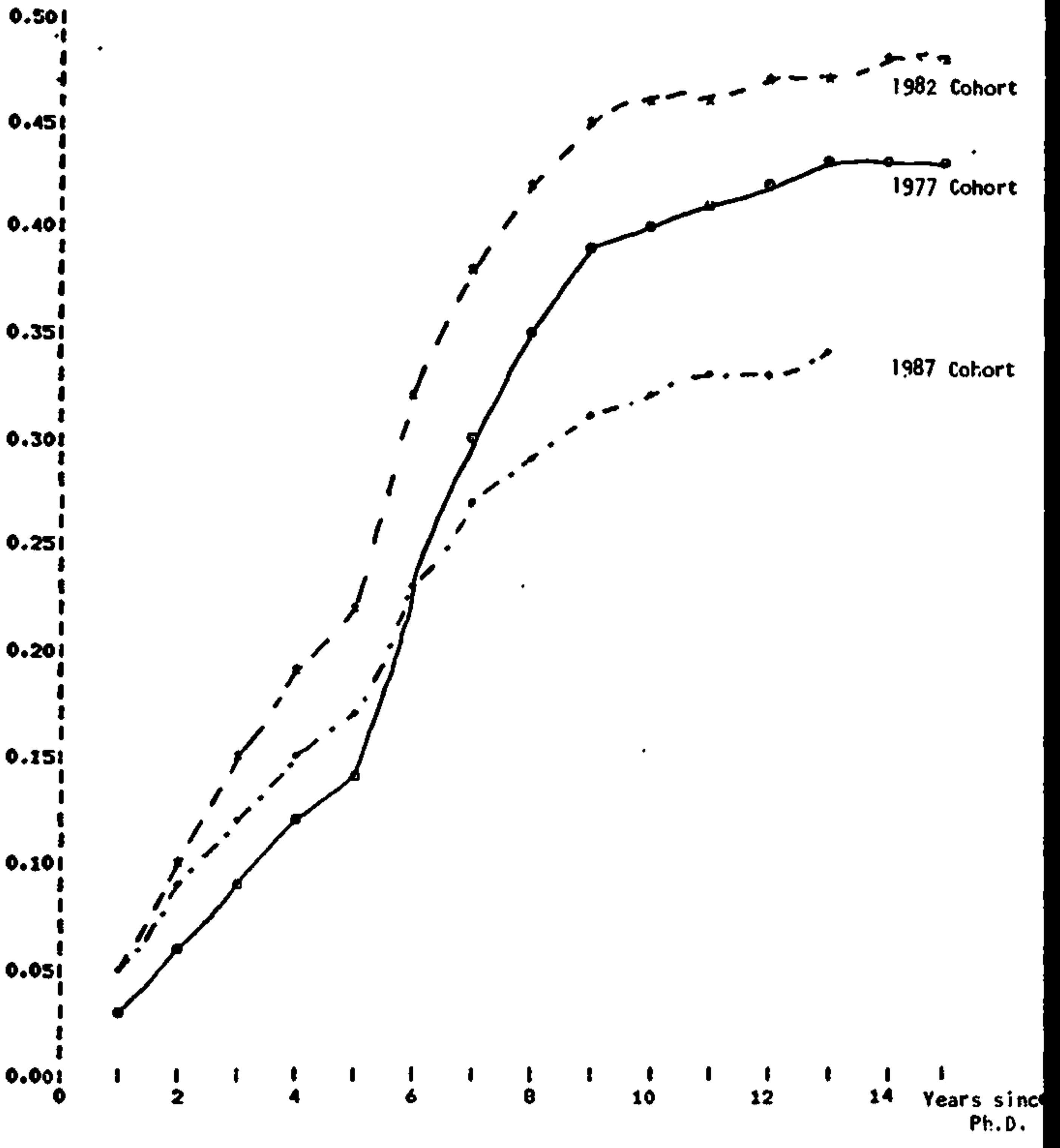
*Based on Kuh/Radner model using CHR data.



CUMULATIVE FRACTION OF PH.D. COHORT RECEIVING TENURE
(Kuh/Radner Projection Based on CHR Data)

——— 0 1977 Cohort
– – – – x 1982 Cohort
– . – . . 1987 Cohort

FIGURE 3.10



CUMULATIVE FRACTION OF PH.D. COHORT LEAVING ACADEMIA

(Kuh/Radner Projection Based on CHR Data)

——— O 1977 Cohort

- - - - x 1982 Cohort

— . — . • 1987 Cohort

FIGURE 3.11

model of the Kuh-Radner variety may reveal fluctuations in the demand for new faculty that may be detrimental to the production of research. Such fluctuations may be missed if an NSF-type projection methodology is used. On the other hand, the highly aggregated nature of our model seriously limits its usefulness. Different fields have different characteristic age structures of both their current faculty stock and of the production of knowledge. (David Riesman distinguishes between "wisdom fields" and "beauty queen fields" to make this point.) A policy designed on aggregate data may treat everyone sensibly on average but everyone unfairly in particular. Thus, the field-by-field approach of the NSF is certainly preferable. Such an approach, however, needs good data if it is to be successful.

Right now the data aren't very good. The fundamental prediction in both types of model is a series of new hires that has a particular age structure. In fact, however, data on new hiring in academia aren't collected, let alone data relating to the age structure of these new hires. Our models calculate new hires as a residual. In doing so, we assume a given relation between baccalaureates or enrollments and faculty demand. We use 1977 CHR data and the NSF uses the results of a 1972-73 sample survey to estimate an age structure of faculty. Thus; new hiring depends on a faculty/student ratio, which we don't directly observe, and on an age structure which may be changing rapidly at the lower end, and estimates of which may be subject to question. Further, we do not have a time series of new hires which would allow us to test the validity of our model on historical data.

There are also data problems in projecting or monitoring institutional behavior. For example, suppose that the institutional response to the predicted decline in new faculty in the 1980's was to increase the number of part-time appointments, or raise faculty/student ratios, or switch to a "three year up or out" policy? How could we observe such changes from data collected by the CHR, NSF or NCES with enough timeliness that we could make recommendations for a budget that wouldn't be spent until a year later?

The essentially demographic models described in this paper are marginal improvements on those described by Allan Cartter thirteen years ago. At the time, he was protesting against naively extrapolative models. By extending the coverage, and perhaps the frequency, of surveys such as those conducted by CHR and NSF, one could collect the data needed to estimate the demographic models properly, and to identify those fields for which demographic projection is an insufficient indicator of future trends in manpower supply and utilization. Then, hopefully, one would be able to formulate models that include economic feedbacks that would add to the richness (and accuracy!) of our methodologies.

In spite of all these caveats, we feel that current projections indicate that there will be a significant trough in the hiring of young doctoral faculty during the next fifteen years, and that the situation is serious enough to warrant some intervention such as the Junior Scholars Program discussed in our earlier report.

REFERENCES

Fernandez, L. U.S. Doctorate Faculty After the Boom: Demographic Projections to 1995, Technical Report No. 4, Carnegie Council on Policy Studies in Higher Education, October 1978.

Kuh, C. V. Market Conditions and Tenure for Ph.D.'s in U.S. Higher Education: Results from the 1975 Carnegie Faculty Survey and A Comparison with Results from the 1973 ACE Survey, Technical Report No. 3, Carnegie Council, July 1977.

________ and R. Radner. Market Conditions and Tenure in Higher Education: 1955-1973, Technical Report No. 2, Carnegie Council, July 1977.

____________________. Mathematicians in Academia; 1975-2000. Conference Board of Mathematical Sciences, 1980.

National Research Council. Commission on Human Resources, Doctoral Scientists and Engineers in the United States - 1975 Profile, National Academy of Sciences, Washington, D.C., 1976.

National Science Foundation. Projections of Science and Engineering Doctorate Supply and Utilization 1982 and 1987. Washington, D.C.: 1979 (NSF 79-303)

Radner, R. and C. V. Kuh. Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000. A Report to the Carnegie Council on Policy Studies in Higher Education, October 1978.

APPENDIX I

RESULTS OF SIMULATIONS FOR CHR-DATA-BASED DOCTORAL MODEL, NSF-1, AND NSF-2*

*Results are reported here for every fifth projected year. A full set of results is available from the authors on request.

CHR

CHR-BASED PROJECTIONS SCALED TO NSF'S 1977 S/E FACULTY STOCK

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1977	1982	1987	1992	1997
Biological Age Distribution of Tenured Faculty					
Ages					
26 - 30	.004	.003	.001	.002	.002
31 - 35	.086	.033	.023	.021	.019
36 - 40	.205	.142	.077	.063	.067
41 - 45	.196	.229	.170	.107	.096
46 - 50	.177	.193	.238	.187	.128
51 - 55	.145	.164	.192	.246	.201
56 - 60	.115	.126	.155	.190	.250
61 - 65	.059	.087	.103	.133	.168
66 - 70	.014	.024	.043	.051	.069
Of Non-Tenured Faculty					
Ages					
26 - 30	.149	.176	.159	.123	.188
31 - 35	.352	.354	.339	.361	.308
36 - 40	.246	.227	.239	.242	.235
41 - 45	.114	.120	.124	.130	.131
46 - 50	.065	.061	.069	.071	.071
51 - 55	.036	.032	.035	.039	.037
56 - 60	.021	.01?	.019	.019	.019
61 - 65	.011	.011	.011	.010	.009
66 - 70	.004	.004	.005	.004	.003
Median Biological Age					
(Ten Fac)	46.23	48.42	50.84	53.40	55.76
(Non-Ten)	35.98	35.51	36.04	36.26	36.08
Faculty of Academic Age Seven or Less					
(Number)	47731	43048	30421	30156	32636
(Fraction)	0.309	0.260	0.195	0.202	0.218
Faculty Tenure Proportion					
	.699	.725	.769	.765	.707
New Hires					
	6630	6283	5727	2798	8156
Deaths and/or Retirements					
	2276	2493	3509	4178	4733
Total Number of Faculty					
	154631	165473	156370	149366	149402
Aggregate Quitrates					
(Ten Fac)	.0001	.0002	.0002	.0001	.0001
(Non Ten)	.0332	.0622	.0887	.0454	.0284
Promotion Rates					
	.1119	.0902	.0589	.0617	.0754
Aggregate Death and Retirement Rates					
	.015	.0151	.0223	.0274	.0322

NSF - 1

NSF PARAMETERS AND CONSTRAINED DEMOGRAPHIC DEMAND

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1977	1982	1987	1992	1997
Biological Age Distribution of Tenured Faculty					
Ages					
26 - 30	.010	.004	.002	.002	.003
31 - 35	.120	.050	.045	.035	.029
36 - 40	.192	.195	.118	.096	.092
41 - 45	.198	.204	.213	.142	.124
46 - 50	.163	.186	.200	.222	.155
51 - 55	.150	.147	.175	.202	.228
56 - 60	.101	.130	.133	.172	.202
61 - 65	.060	.084	.115	.128	.167
66 - 70	.006	.000	.000	.000	.000
Of Non-Tenured Faculty					
Ages					
26 - 30	.152	.214	.201	.149	.272
31 - 35	.488	.419	.421	.459	.414
36 - 40	.210	.216	.221	.228	.181
41 - 45	.084	.089	.090	.093	.077
46 - 50	.041	.041	.043	.045	.038
51 - 55	.019	.016	.017	.018	.014
56 - 60	.005	.005	.005	.005	.004
61 - 65	.002	.001	.001	.001	.001
66 - 70	.000	.000	.000	.000	.000
Median Biological Age					
(Ten Fac)	45.49	47.23	48.86	51.04	53.24
(Non-Ten)	34.31	34.19	34.45	34.67	33.59
Faculty of Academic Age Seven or Less					
(Number)	71639	63407	46841	43733	47568
(Fraction)	0.463	0.374	0.285	0.272	0.290
Faculty Tenure Proportion					
	.654	.682	.762	.773	.737
New Hires					
		8723	7718	3656	10009
Deaths and/or Retirements					
		1961	2817	3755	4146
Total Number of Faculty					
	154631	169598	164167	160538	164301
Aggregate Quitrates					
(Ten Fac)					
(Non-Ten)		.0927	.1274	.0632	.0689
Promotion Rates					
		.08[illegible]	.0996	.0853	.064
Aggregate Death and Retirement Rates					
		.0117	.0171	.023	.0257

NSF - 2

NSF PARAMETERS AND A TWO-SEGMENT LINEAR DEMAND

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

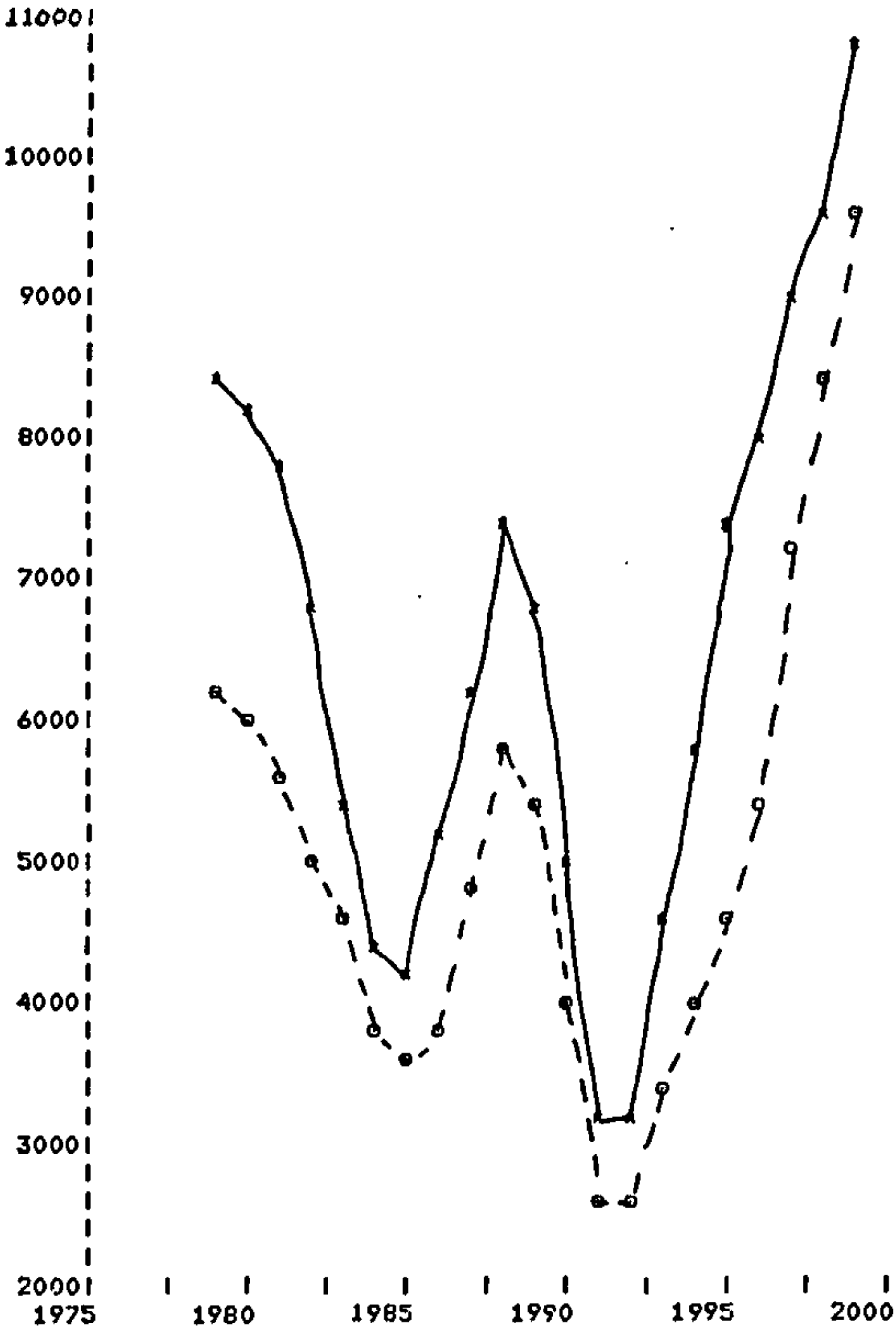
Projected Years

	1977	1982	1987	1992	1997
Biological Age Distribution of Tenured Faculty					
Ages					
26 - 30	.010	.003	.003	.003	.003
31 - 35	.120	.047	.042	.040	.042
36 - 40	.192	.195	.105	.100	.104
41 - 45	.198	.204	.213	.131	.128
46 - 50	.163	.187	.203	.220	.141
51 - 55	.150	.148	.179	.203	.220
56 - 60	.101	.131	.137	.173	.197
61 - 65	.060	.085	.118	.130	.164
66 - 70	.006	.000	.000	.000	.000
Of Non-Tenured Faculty					
Ages					
26 - 30	.152	.218	.208	.208	.220
31 - 35	.488	.410	.426	.431	.426
36 - 40	.210	.220	.214	.210	.205
41 - 45	.084	.090	.088	.087	.085
46 - 50	.041	.041	.042	.042	.041
51 - 55	019	.016	.017	.016	.016
56 - 60	.005	.005	.005	.005	.005
61 - 65	.002	.001	.001	.001	.001
66 - 70	.000	.000	.000	.000	.000
Median Biological Age					
(Ten Fac)	45.49	47.31	49.19	51.15	53.01
(Non-Ten)	34.31	34.27	34.28	34.20	34.06
Faculty of Academic Age Seven or Less					
(Number)	71639	54315	50571	53435	56607
(Fraction)	0.463	0.338	0.308	0.318	0.330
Faculty Tenure Proportion					
	.654	.716	.739	.727	.715
New Hires					
		8195	7517	7865	8750
Deaths and/or Retirements					
		1952	2811	3749	4137
Total Number of Faculty					
	154631	160506	164167	167828	171489
Aggregate Quitrates					
(Ten Fac)					
(Non-Ten)		.1088	.0921	.0752	.081
Promotion Rates					
		.0866	.088	.082	.0803
Aggregate Death and Retirement Rates					
		.0123	.0172	.0224	.0242

70

DOCTORAL NEW HIRES: THREE YEAR MOVING AVERAGE

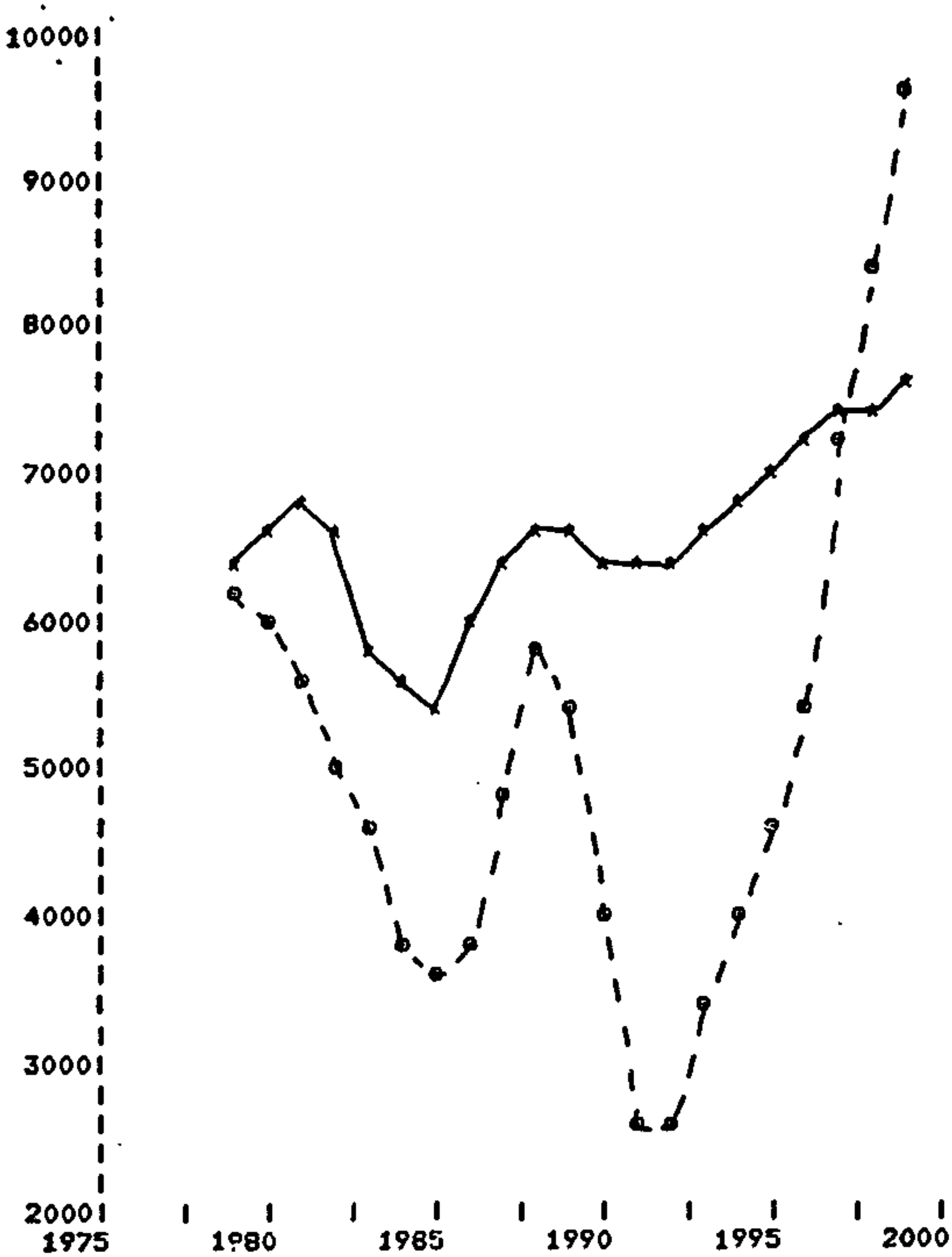
YEAR	CHR-BASEO OATA	NSF-1	NSF-2
1979	6219	8497	6392
1980	6056	8266	6527
1981	5674	7831	6725
1982	4998	6862	6620
1983	4552	5425	5890
1984	3860	4363	5509
1985	3578	4100	5439
1986	3831	5198	6065
1987	4758	6293	6360
1988	5787	7405	6575
1989	5410	6739	6663
1990	4097	4935	6402
1991	2676	3170	6319
1992	2617	3200	6343
1993	3437	4636	6618
1994	3991	5837	6788
1995	4664	7308	7058
1996	5445	8003	7284
1997	7160	9054	7320
1998	8497	9660	7422
1999	9534	10842	7617



DOCTORAL NEW HIRES: THREE YEAR MOVING AVERAGE

- - - - θ CHR-BASED DATA

——— x NSF-1



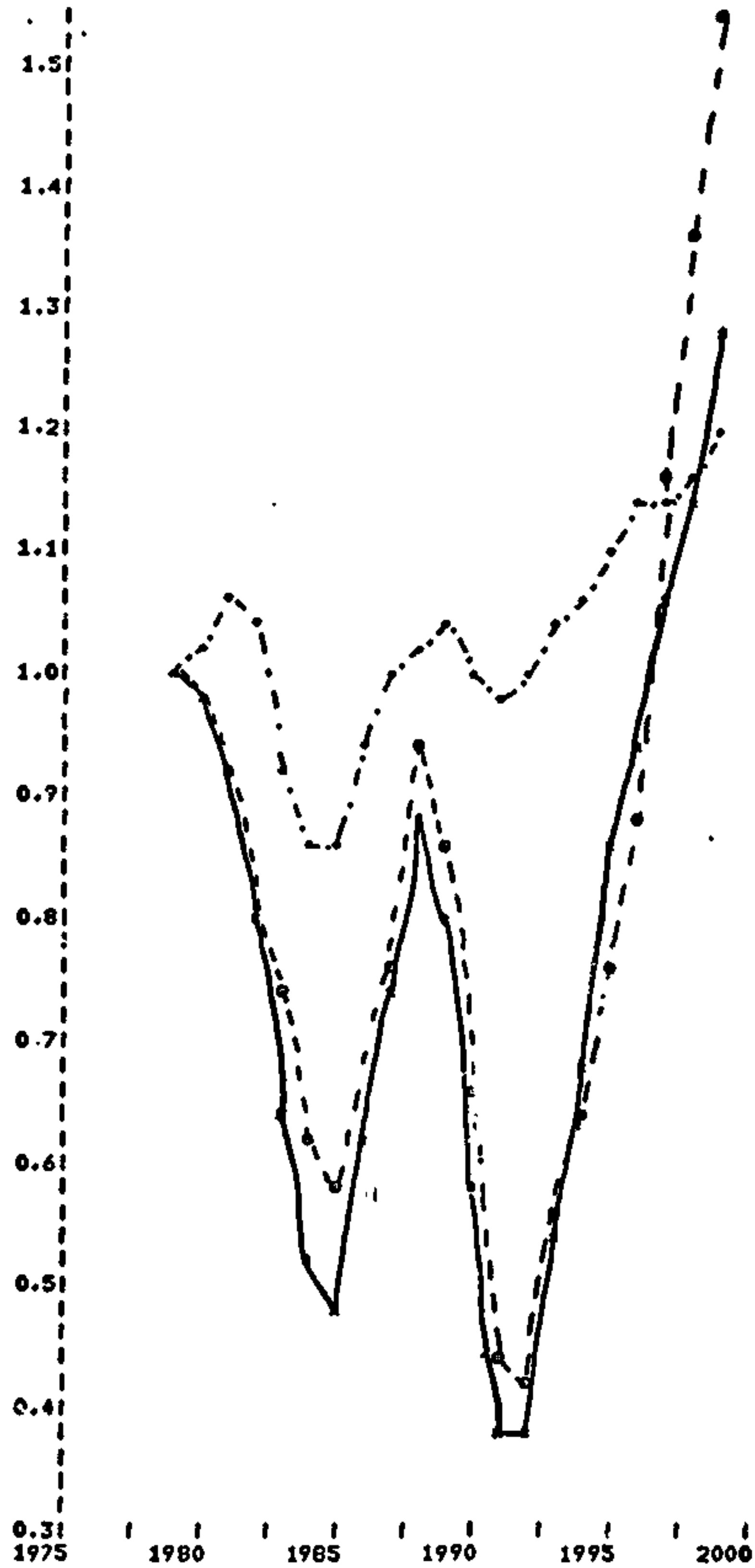
DOCTORAL NEW HIRES: THREE YEAR MOVING AVERAGE

– – – – 0 CHR-BASED DATA

———— x NSF-2

RELATIVE DOCTORAL NEW HIRES: THREE YEAR MOVING AVERAGE

YEAR	CHR-BASED DATA	NSF-1	NSF-2
1979	1	1	1
1980	0.9738	0.9729	1.0211
1981	0.9124	0.9217	1.0521
1982	0.8036	0.8076	1.0357
1983	0.732	0.6385	0.9215
1984	0.6208	0.5136	0.8619
1985	0.5754	0.4826	0.8509
1986	0.6161	0.6118	0.9489
1987	0.7651	0.7406	0.995
1988	0.9306	0.8715	1.0286
1989	0.8699	0.7932	1.0424
1990	0.6588	0.5808	1.0016
1991	0.4303	0.3731	0.9886
1992	0.4209	0.3767	0.9923
1993	0.5526	0.5456	1.0354
1994	0.6418	0.687	1.0619
1995	0.75	0.8602	1.1041
1996	0.8756	0.9419	1.1396
1997	1.1513	1.0656	1.1452
1998	1.3663	1.137	1.1612
1999	1.5331	1.276	1.1916



RELATIVE DOCTORAL NEW HIRES: A THREE YEAR MOVING AVERAGE

- - - - o CHR-BASED DATA
——— x NSF-1
-.-. . NSF-2

APPENDIX II

CHR-DATA-BASED PROJECTIONS OF
DOCTORATE FACULTY*

*Results are reported here for every fifth projected year. A full set of results is available from the authors upon request.

CHR-BASED PROJECTIONS OF DOCTORATE FACULTY

	Projected Years				
	1977	1982	1987	1992	1997
Biological Age Distribution of Tenured Faculty					
Ages					
26 - 30	.004	.003	.001	.002	.002
31 - 35	.026	.033	.023	.021	.019
36 - 40	.205	.142	.077	.063	.067
41 - 45	.196	.229	.170	.107	.096
46 - 50	.177	.193	.238	.187	.128
51 - 55	.145	.164	.192	.246	.201
56 - 60	.115	.126	.155	.190	.250
61 - 65	.059	.087	.103	.133	.168
66 - 70	.015	.024	.043	.051	.069
Of Non-Tenured Faculty					
Ages					
26 - 30	.149	.176	.159	.123	.188
31 - 35	.352	.354	.339	.361	.308
36 - 40	.246	.227	.239	.242	.235
41 - 45	.114	.120	.124	.130	.131
46 - 50	.065	.061	.069	.071	.071
51 - 55	.036	.032	.035	.039	.037
56 - 60	.021	.017	.019	.019	.019
61 - 65	.011	.011	.011	.010	.009
66 - 70	.004	.004	.005	.004	.003
Median Biological Age					
(Ten Fac)	46.23	48.42	50.84	53.40	55.76
(Non-Ten)	35.98	35.51	36.04	36.26	36.08
Faculty of Academic Age Seven or Less					
(Number)	60597	54651	38621	38285	41433
(Fraction)	0.309	0.260	0.195	0.202	0.218
Faculty Tenure Proportion					
	.699	.725	.769	.765	.707
NEW HIRES					
	8417	7976	7271	5552	10355
Deaths and/or Retirements					
	2889	3165	4455	5305	6009
Total Number of Faculty					
	196312	210076	198520	189628	189674
Aggregate Quitrates					
(Ten Fac)	.0001	.0002	.0002	.0001	.0001
(Non-Ten)	.0332	.0622	.0887	.0454	.0284
Promotion Rates					
	.1119	.0902	.0589	.0617	.0754
Aggregate Death and Retirement Rates					
	.015	.0151	.0223	.0274	.0322

CHAPTER IV

ALTERNATIVE APPROACHES TO MODELING THE DEMAND FOR SCIENCE AND ENGINEERING FACULTY

Donald J. Hernandez
Social Science Research Council

The results presented in the two preceding papers of this volume are somewhat puzzling because, despite their broad qualitative agreement on the nature of future developments in the market for science and engineering faculty, the Kuh-Radner and the NSF attempts to account for quantitative differences in projected trends are at odds. NSF projects a smaller decline in hiring and in the proportion of young faculty than does Kuh-Radner. The Kuh-Radner analysis of the alternative projections implies that the bulk of this difference results from different assumptions about the time-pattern of student demography and faculty demand, but NSF's analysis attributes a much smaller proportion of the difference in projections to this source, citing differences in assumptions about promotion rates and staff upgrading as more important.

The purpose of this paper is to explore further the reasons for the differences in the NSF and Kuh-Radner projections. Although available data and analyses do not permit a complete resolution of these differences, the comparison of the two studies does serve to clarify similarities and differences in their approach, and to point up important methodological issues which arise in comparing studies that differ in modeling techniques as well as empirical assumptions.

To begin this discussion, a general model for projecting the demand for new faculty in higher education is briefly described. The model can be conceived as consisting of two analytically distinct components, a growth component and a replacement component (Cartter, 1976, p. 120). First, since growth in the total demand for faculty is supplied through hiring new faculty, it implies a corresponding demand for new faculty. Similarly, since a need to replace existing faculty is met through hiring new faculty, it also implies a corresponding demand for new faculty.

For colleges and universities, the growth component in the demand for new Ph.D. faculty can be seen as depending on four factors: the size of the college-age population, the proportion of college-age people who attend college, the faculty-student ratio, and the doctorate faculty-total faculty ratio. The replacement component can also be seen as depending upon four factors: the faculty death rate, the faculty retirement rate, the net rate at which tenured faculty voluntarily move from academia, and the rate of failure to obtain tenure. The extent to which a specific projection of the trend in new hiring is plausible depends both on the nature of its underlying assumptions with regard to these eight factors and on the nature of the projection model that links them.

Before turning to a comparison of the NSF and the Kuh-Radner results, it is useful to summarize their approaches, as described both in their papers in this volume and in their earlier work (Radner and Kuh, 1978; NSF, 1979).

1. Radner and Kuh

The Radner and Kuh (1978) analysis draws upon the classic work of Allan M. Cartter (1976) to project the demand for new doctoral faculty throughout academia, the setting in which the majority of scientists and engineers work and in which the majority of basic research is conducted. In order to project the demand for new faculty through growth, Radner and Kuh employ: (1) U.S. Census projections of the number of people in the prime college ages, (2) Cartter's (1976) assumptions about the propensity of the prime college-age population to enroll in college, (3) a constant faculty-student ratio (1 to 17), and (4) a constant doctorate faculty-total faculty ratio (1 to 2). To project the demand for new faculty through replacement, Radner and Kuh employ the following assumptions: (1) a constant death rate based on U.S. Public Health Service data for males, (2) a faculty retirment rate which implies a median age of retirement of about 66 in 1976, rising to about 69 in 1983, and remaining constant thereafter, (3) a net attrition rate for tenured faculty that rises from 4.8 percent in 1976 to 8.7 percent in 1985 and 1986, and then falls to

4.8 percent in 1995 and thereafter, and (4) a nontenured retention rate after seven years that falls from .7 for the 1977 cohort to about .6 for the 1982 cohort, and then rises to above .7 for the 1987 cohort.

Formally, the model used to derive the projections is a Markov model with nonstationary transition probabilities. Because the values of parameters in the model are allowed to change on an annual basis, the values of the resulting projections for a specific year depend upon both the particular values of the parameters for that year, and the cumulative effect of fluctuations in the parameters during the preceding years. In other words, the model traces out the year by year evolution of the faculty age distribution, the new hiring required by growth and replacement, the tenure ratio, the proportion of young faculty, and other results, based on the values of parameters which in many cases change annually in a nonlinear fashion. The results of this paper refer to the entire faculty at all four-year colleges and universities.

In a second paper, prepared for this volume (chapter III), Kuh and Radner extend and refine their results by employing more recent data and by deriving estimates specifically for science and engineering faculty. Two major differences distinguish the two sets of projections. First, in the more recent projections, the initial age and tenure distribution and number of doctoral faculty in 1975 are derived from the 1975 Comprehensive Survey of Doctoral Scientists and Engineers conducted by the Commission on Human Resources (National Research Council, 1976) instead of the Carnegie Council's 1975 Survey of Faculty. Second, the total faculty size is scaled down to a value consistent with the baseline science and engineering faculty stock of the NSF (1979) data base for 1977. With these changes, Kuh and Radner derive a new set of projections.

The resulting analysis implies that the annual demand for new science and engineering doctorates will drop by about 46 percent between 1978 and 1985, will rise to roughly its former level by 1989, but then will fall precipitously by 1991 to 35 percent of the 1978 level (chapter III). Moreover, the ratio of recent to total Ph.D. science and engineering faculty is projected to fall to an average of 25 percent below its 1977 level between 1987 and 1996 (chapter III). Insofar as young scholars and/or continuity in the age structure of science and engineering faculty are necessary to the health and productivity of basic research, these trends suggest that without policy intervention the vitality of science in the U.S. may fall short of its potential during the coming years.

Perhaps the most obvious limitation of these projections is the method of deriving college and university enrollment. The procedure assumes that fluctuations in enrollment are determined primarily by fluctuations in the size of the prime college-age population, but the demand for college graduates due to economic change might also influence the college enrollment rate.

II. National Science Foundation

For the purpose of this analysis, the National Science Foundation (NSF, 1979) projections can be distinguished from those of Radner and Kuh in four important respects. First, the NSF projects the demands for science and engineering doctorates both for higher education and for other sectors of the economy. The projections for higher education are discussed here. Second, the NSF develops a separate forecast for each of the broad fields within science and engineering, and combines the results to obtain an aggregate projection. Third, the NSF bachelor's degree projections that underlie its total faculty demand projections are derived without explicitly incorporating distinct mathematical assumptions regarding the future size of the prime college-age population. Fourth, with regard to most of the basic parameters and modeling procedures, the NSF assumes either constancy or a linear pattern of change over time.

In order to project the demand for new faculty in the physical sciences, the mathematical sciences, the life sciences, and engineering, the NSF begins by regressing past numbers of faculty in each field on both past numbers of bachelor's degrees and a time trend variable related to past bachelor's degrees. Projections of future bachelor's degrees are then inserted into the regression equations to obtain projections for the future faculty size of colleges and universities. The degree projections that are used for the physical sciences, mathematics, and the life sciences assume that "trends existing as of 1976 in the numbers of baccalaureate degrees awarded by field and sex will continue through 1987. The rate of change, however, is assumed to be one-half the current rate (NSF, 1979, p. 2)."

Engineering degrees are projected with an econometric approach that links degree awards to market conditions (NSF, 1979, p. 19). For the social sciences, it is assumed "that total social sciences staff will remain constant during the projection period (NSF, 1979, p. 12)." These procedures produce a relatively large rise in the projected number of bachelor's degrees and a projected increase of six percent in total faculty size between 1977 and 1987.

In chapter II above, the NSF projects the demand for new faculty through replacement by assuming: (1) a constant death rate (the Teachers Insurance and Annuity Association (TIAA) death rate for males), (2) a faculty retirement age of 66 years, (3) a zero percent rate of moves of tenured faculty out of academia, and (4) a rate of failure to obtain tenure of 50 percent after seven years. Finally, it is assumed that 85 percent of all new hires will have Ph.D.'s. The baseline faculty age distribution is based on the 1973 American Council on Education (ACE) Faculty Survey.

With the single exception of engineering degrees, the NSF projection procedures thus assume that the values of all the basic parameters in its model either change in a linear fashion between 1977 and 1987, or do not change at all. From these calculations, the NSF concludes that the proportion of faculty who are young will drop from .41 in 1977 to .33 in 1987.[1/] This 20 percent decline in the proportion of young faculty is considerably less than the 27 percent decline projected by Kuh-Radner (chapter III) for the same period.

III. A Comparison of the Kuh-Radner and NSF Projections

Perhaps the two most obvious questions that emerge from a comparison of the NSF results to the Kuh-Radner (chapter III) results are the following. Why do both projections suggest that a sharp decline will occur between 1977 and 1987 in the proportion of doctoral science and engineering faculty who are young? Why does the Kuh-Radner projection suggest that the decline will be considerably more precipitous than NSF suggests?

The twofold answer to the first question is student demographics and faculty demographics. As a consequence of the postwar baby boom, the number

---

[1/] This change in proportion of young faculty is not reported in chapter II, but it was included in a personal communication from Charles Falk to Fred Balderston (chairman of the Forecasting Workshop), May 19, 1979.

of people aged 18 to 21 jumped by nearly 60 percent between 1957 and 1967 and by an additional 20 percent between 1967 and 1977 (Cartter, 1976, pp. 38-39). These increases were a fundamental force driving the rapid rises in college enrollments and hence total faculty demand during these two decades. The related consequences were a high rate of new faculty hiring in colleges and universities, and by 1977, a relatively young faculty age distribution. Between 1977 and 1987, however, the prime college-age population is projected to fall substantially (Radner and Kuh, 1978). Consequently, both the NSF and Kuh-Radner project an, at least temporary, end to the sharply increasing enrollments that prevail. The result is a decline in the rate of hiring new faculty through growth and an aging of the faculty as a whole.

The effects of these student demographics are magnified by faculty demographics. Because college and university faculty were relatively young by 1977, due to relatively rapid hiring during the preceding two decades, they will experience relatively little attrition due to death and retirement during the following decade, and new faculty hiring through replacement will be relatively slight. The combined effect of these student and faculty demographics between 1977 and 1987 is the projected slowing of new hiring and the concomitant aging of the faculty.

The answer to the second question--Why do Kuh-Radner project a considerably more rapid fall in the proportion of faculty who are young than does the NSF?--remains to be found. Answers can be obtained from the analyses presented by the NSF (chapter II) and by Kuh-Radner (chapter III), but they are quite different. The aim of the following discussion is to describe the source of the differences and to provide a solution to the apparent dilemma.

It is useful to begin with a description of how, other things being equal, we would expect differences between the NSF and Kuh-Radner in the eight major parameters to affect projections of new hiring and of the proportion of faculty who are young.

First, the net effect of the Kuh-Radner assumptions regarding fluctuations in the size of the college-age population, changes in the proportion attending college, and the magnitude of the faculty-student ratio is to produce a projected increase in total faculty size in 1987 that is one percent above the 1977 level. In contrast, the NSF assumption that linear trends in the number of bachelor's degrees will continue (at one-half the pre-1976 rate), when combined with the regression equations it uses to link bachelor's degrees with faculty demand, produces a projected demand in total faculty that increases six percent during the decade. Because the NSF projections call for more rapid faculty growth, the NSF projections indicate a correspondingly rapid rate of new faculty hiring. This difference between the NSF and Kuh-Radner projections implies that, _ceteris paribus_, the age distribution of faculty according to the NSF projection will be relatively young in 1987, compared to that projected by Kuh-Radner. Although both projections call for a decline in the proportion of faculty who are young, this difference between the two projections should lead to a slower decline for the NSF projection.

Second, the NSF assumes that 85 percent of all new faculty hired will have a Ph.D. Kuh-Radner assume that the present level of 50 percent Ph.D.'s for all faculty will apply to future new hiring. The result of this difference is that, _ceteris paribus_, the NSF would project a larger number of new Ph.D.'s hired than would Kuh and Radner, resulting in a slower NSF decline in the proportion of faculty who are young.

Third, the NSF obtained its estimates of faculty death rates from TIAA data for males. Radner and Kuh employ U.S. Public Health Service data for males. Since faculty death rates are less than those of the general population, this difference in assumptions suggests that, _ceteris paribus_, the NSF should project less new hiring and a faster decline in the proportion of young faculty.

Fourth, the NSF assumes that all faculty will retire at age 66. Kuh and Radner assume a rise in the median age of retirement from about 66 in 1976 to about 69 in 1982. Because the earlier retirment assumed by the NSF moves senior faculty out of academia more quickly, it tends to produce a doctoral faculty with a younger age distribution, and a slower decline in the proportion of young faculty.

Fifth, the NSF assumes no net movement of tenured faculty out of academia (other than through retirement or death), but Kuh and Radner assume a positive movement out that rises and then falls during the projection period. This difference would tend to produce an older age distribution for the NSF projections, and a more rapid decline in the proportion of young.

Finally, the NSF assumes that 50 percent of all new faculty are retained after seven years, and 50 percent leave the system during the seventh year. Kuh and Radner assumptions imply that 70 percent of the 1977 cohort will still be in academia after seven years. The NSF assumption, that a smaller proportion of new hires will be retained after seven years, implies relatively more new hiring to replace them, and hence a relatively young age distribution by 1987, and a slower decline in the proportion of faculty who are young.

In sum, differences between these studies in the effects of six of the eight major assumptions imply that compared to Kuh-Radner projections, the NSF age distribution of faculty would be younger and the proportion of young faculty would fall more slowly.[2/] It is not surprising, then, that the ratio of young doctoral faculty to senior doctoral faculty falls more slowly according to NSF projections, 20 percent versus 27 percent. This analysis does not account for any differences in the results that derive from the alternative modeling procedures employed, however. Nor does it indicate the relative importance for the magnitude of the final results of differences in the assumptions about specific parameters. Discussion turns to these issues.

[2/] Although a difference in definitions of recent and young faculty is noted by the NSF in chapter II of this volume in its comparison of NSF (1979) and Radner and Kuh (1978) results, Kuh and Radner (chapter III) employ the same definition of recent and young faculty as the NSF, and the distinction is not pursued further here. With this change, the NSF (chapter II) analysis may be translated into a comparison based on Kuh and Radner (chapter III) as summarized in Table 4.1. Although different initial age distributions of faculty in the two sets of projections are also of some importance, the impact of this difference cannot be ascertained from information at hand.

Based on the results in Table 4.1, the NSF (chapter II) analysis implies that differences in the proportion of nontenured staff retained and in the doctorate faculty-total faculty ratio account for most of the difference between the NSF results and the Kuh-Radner results. In contrast, the comparisons developed by Kuh and Radner seem to imply that differences in the time profile in the total number of staff employed are overwhelmingly important in explaining the sharper decline in the proportion of young faculty projected by Kuh and Radner. Why are these interpretations quite different? Before answering this question, it is necessary to discuss the manner in which these interpretations are obtained.

The NSF derived its estimates of the importance of differences in each of the parameters with the following procedure.[3] For each parameter, the NSF began with its own model and then substituted for the NSF value of a specific parameter the value employed by Kuh-Radner. Because Kuh-Radner values were substituted for NSF values one at a time, this procedure answers the following question. Given the specific methodological procedures of the NSF model, and given the array of NSF assumptions regarding parameter values, what is the effect on the final results of substituting the Kuh-Radner values for one specific parameter? This question is, in effect, asked individually for each of the parameter values tested and the results are presented by the NSF in chapter II and in Table 4.1.

Although this procedure allows the NSF to distinguish the impact of differences in parameter values given its basic model, it does not allow the NSF to assess the joint effect of differences between the NSF approach and the Kuh and Radner approach both with regard to parameter values and with regard to modeling procedures that define the way in which parameters are linked to each other. For example, the NSF model assumes that changes in most of its basic parameter values occur in a linear fashion (or not at all). More specifically, the NSF assumes that (with the exception of engineering) changes in the total number of faculty required for each field

[3]Personal communication with Larry Lacy of the NSF.

TABLE 4.1

DIFFERENCES BETWEEN NSF AND KUH-RADNER
PROJECTIONS OF "RECENT" FACULTY RATIOS

	NSF	KUH-RADNER	DIFFERENCE
1986-87 RECENT FACULTY PERCENTAGE	33%	19%	14%

SOURCE OF DIFFERENCE	ESTIMATED DIFFERENCE FROM NSF PROJECTION MODEL (IN PERCENTAGE POINTS)	CUMULATIVE DIFFERENCE
TOTAL	-14	--
PROPORTION OF NONTENURE STAFF RETAINED	-7	-7
ABSENCE OF STAFF UPGRADING	-4	-11
NUMBER OF ACADEMIC STAFF EMPLOYED	-3	-14
DEATH RATES	+2	-12
RETIREMENT AGE	-1	-13
UNACCOUNTED FOR	-1	-14

Source: Derived from NSF data in chapter II as described in text.

occur in a strictly linear fashion. Consequently, in estimating the impact on the proportion of faculty who are young of a shift to Kuh-Radner enrollment and total faculty size assumptions, the NSF notes that by 1987, total faculty demand in the Kuh-Radner analysis is one percent more than the 1977 value. Hence, the NSF replaces its six percent estimate in its model with the one percent estimate assuming, in effect, that the corresponding change projected by Kuh and Radner was a linear one.

This procedure poorly reflects the trend in the Kuh-Radner estimates which implies a seven percent growth in total faculty demand between 1977 and 1982, followed by a decline of roughly six percent between 1982 and 1987. The rise and the fall in faculty demand, as projected by Kuh-Radner, are due to shifts in student demographics associated with fluctuations in the number of people in the prime college ages, shifts which the NSF procedure does not explicitly take into account. Such nonlinear changes in total faculty demand and the resulting changes in new hires have an important effect on the projections of the faculty age distribution. The inability of the NSF procedure to assess the impact of such nonlinear changes limits the value of the NSF analysis as a means of assessing the reasons--parameter shifts and modeling procedure differences--that explain why Kuh and Radner project a relatively sharp fall in the proportion of faculty who are young.

In assessing the importance of parameter differences and methodological differences between the two sets of projections, Kuh and Radner employ a different approach. They develop three sets of projections. The first, referred to as the CHR-data-based doctoral model, is the one described above in the section on their projections. It suggests that the proportion of faculty who are young will decline by 27 percent between 1977 and 1987.

The second projection, referred to as NSF-1, employs NSF (1979) parameter values and baseline data, and takes as given the total faculty stock estimate of the NSF for 1977 and the NSF projected value of the stock for 1987. It further assumes, however, that total faculty stocks fluctuate through time according to the pattern developed in the CHR-data-based doctoral model. This is equivalent to substituting the Kuh-Radner assumption regarding the nature of fluctuations in student demographics and total faculty demand for the actual NSF assumptions of nearly linear change. In addition, the NSF-1 modeling procedure allows promotion rates, death rates, and retirement rates to act through the changing annual projections of the age/tenure distribution of the faculty, distinguishing it from the NSF modeling procedure which uses simplifying "linear change" assumptions.

The third projection, referred to as NSF-2, also employs NSF parameter values, baseline data, and total faculty stock estimates for 1977 and 1987, but it also takes as given the NSF projections of the 1982 total faculty stock. It then interpolates linearly between the 1977 and 1982 faculty stocks and the 1982 and 1987 faculty stocks. This assumption is consistent with the NSF assumption regarding student demographics and total faculty demand. As in NSF-1, NSF-2 allows promotion, death, and retirement rates to act through the changing annual projections of the age/tenure distribution.

Kuh and Radner were not able to replicate some of the NSF data and procedures, however. Specifically, instead of using the age/tenure distributions employed by the NSF, they substituted the CHR-data-based distribution, and instead of employing the NSF doctoral/nondoctoral faculty structure, approximating assumptions were substituted. Aside from these deviations from the NSF model and the application of promotion, death, and retirement rates to each annual projection of the faculty distribution, NSF-2 is designed to replicate the actual NSF parameter values and procedures.

The only difference between the derivation of NSF-1 and NSF-2 is that NSF-1 is derived with the Kuh-Radner student and total faculty demand dynamics but NSF-2 is derived with procedures that replicate the actual NSF student and faculty demand dynamics. In other words, NSF-1 assumes that student enrollments and total faculty demand respond through time primarily to changes in the size of the prime college-age population. In contrast, NSF-2 assumes a nearly linear increase in the number of baccalaureate degrees awarded, which may be viewed as a proxy for student enrollments, and linear changes in total faculty demand.

Consequently, the difference between NSF-1 and NSF-2 in the percentage decline in the proportion of faculty who are young can be seen as estimating the impact of the difference between the Kuh-Radner assumptions and the NSF assumptions regarding the time pattern of student demographics and total faculty demand. Subtracting the NSF-1 value of 24 percent from the NSF-2 value of 30 percent, produces an estimated impact of six percent. Since the difference between the actual NSF (1979) estimate of this decline (20 percent) and the Kuh-Radner estimate from the CHR-data-based doctoral model (27 percent) is seven percent, one can attribute 6/7 of the difference to the fact that Kuh-Radner and the NSF employ different assumptions regarding student demographics and total faculty demand. This is much larger than the corresponding estimate of 3/14 obtained from NSF calculations above. Why is there a large difference between these two estimates and the corresponding interpretations?

In both the NSF mode of comparison and the Kuh-Radner mode of comparison, the magnitude of the estimated effect of a specific difference in a parameter value or a modeling procedure is influenced by both the other parameter values and the particular modeling procedure actually employed in developing the comparison. In other words, the magnitude of the 3/14 estimate of the NSF depends partly on the importance of the different student demography and faculty demand assumptions, but it also depends partly on other specific parameter values and the modeling procedure the NSF employs in deriving the 3/14 estimate. Similarly, the 6/7 estimate derived from the Kuh and Radner mode of comparison depends partly on the importance of the different student demography and faculty demand assumptions, but it also depends partly on the other specific parameter values and the modeling procedure that Kuh and Radner employ in deriving the 6/7 estimate.

In short, an unequivocal answer cannot be derived for the question, "Why do Kuh and Radner project a sharper drop in the proportion of faculty who are young?" This entanglement of differences in assumptions and in modeling procedures is a familiar problem in other contexts, including macroeconomic forecasting. The controversy between the monetarists and the Keynesians about the relative importance of fiscal and monetary variables in affecting the level of economic activity is an example. This controversy has defied resolution partly because the two camps disagree not just about empirical assumptions and results, but also about the appropriate framework to employ in modeling the economy.

Lacking a method to resolve conclusively the question of why projections of the proportions of young faculty differ, the most reasonable approach may be simply to average the answers offered by NSF and Kuh-Radner, on the assumption that this procedure roughly averages the effects of the other differences in modeling procedures and assumptions. If this solution is adopted as the most reasonable convention, it suggests that the differences in student demography and faculty demand assumptions between the NSF and the Kuh-Radner projections account for about half of the difference in the percentage decline between 1977 and 1987 in the proportion of faculty who are young. This resolution to the problem suggests that the different assumptions with regard to student demographics and faculty demand are important, probably the most important, parts of the explanation for the difference in the results from the two sets of projections. If so, the relative plausibility of these assumptions is a crucial factor in determining the relative plausibility of the results. In the judgment of this observer, the trend in student enrollments and hence the trend in total faculty demand assumed by Kuh and Radner appears to be more plausible than the NSF assumptions regarding these trends.

As noted above, the Kuh-Radner projection explicitly assumes that college enrollments will respond to future nonlinear fluctuations in the size of the prime college-age population. The NSF, on the other hand, does not incorporate explicit mathematical assumptions regarding these fluctuations, but instead linearly extrapolates past trends in the number of bachelor's degrees for each field (at one-half the pre-1976 rate).[4/] The result is projected estimates of the total future number of bachelor's degrees that increase linearly through time. If, instead, the number of bachelor's degrees

---

[4/] Engineering degrees are the exception, as discussed above. It should also be noted that the NSF (1979) does compare the results of its degree projections for science and engineering to the results of projections developed by the National Center for Education Statistics (NCES, 1978) for all bachelor's and first professional degrees. It finds the result to be consistent with historical data. It has been argued elsewhere (Hernandez, 1979), that the NCES projections may also overestimate future enrollments, however.

responds to fluctuations in the size of the prime college-age population, this NSF assumption will, other things being equal, tend to produce an overestimate of the future number of bachelor's degrees, of the future total demand for doctoral faculty, and of future hiring. The consequence would be an underestimate of the future decline in the proportion of science and engineering faculty who are young.

IV. Conclusion

The two recent projection studies discussed here indicate that, with the impending halt to rapid increases in student enrollments, and with a faculty age distribution which implies relatively little faculty attrition due to death and retirement, new hiring of doctoral science and engineering faculty in U.S. colleges and universities will fall sharply during the next decade. The studies indicate that a major consequence will be a 1977-87 decline of between 20 and 27 percent in the proportion of doctoral faculty who are young.

The present review suggests that one important, perhaps the most important, determinant of the difference between the 20 percent estimate of the NSF study and the 27 percent estimate of the Kuh-Radner study lies in their different assumptions regarding the responsiveness of future student enrollments and bachelor's degrees to fluctuations in the number of people in the prime college areas. Since Kuh and Radner assume greater responsiveness to these fluctuations, their estimate appears to be more plausible.

Despite the important differences between the results of the studies, however, the general agreement between them regarding the trends in new hiring and the aging of science and engineering faculty should be emphasized. To the extent that either a flow of new faculty into colleges and universities or continuity in the age structure of faculty is important to the health and vitality of science and engineering in the U.S., the projected changes do not bode well for the vigor of basic research during the coming years.

REFERENCES

Cartter, A. M. Ph.D.'s and the Academic Labor Market. New York: McGraw-Hill, 1976.

Hernandez, D. J. A Review of Projections of Demand for Ph.D. Scientists and Engineers, Appendix B of Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. Washington, D.C.: National Academy of Sciences, 1979.

Kuh, C. V. and R. Radner. Reconcilable Differences? An Examination of Alternative Projections of Academic Demand for Recent Science and Engineering Ph.D.'s in the 1980's. Prepared for the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers. Washington, D.C.: National Research Council, April 30-May 1, 1979 (preliminary).

National Center for Education Statistics. Projections of Education Statistics to 1986-1987. Washington, D.C.: United States Government Printing Office, 1978.

National Research Council, Commission on Human Resources. Doctoral Scientists and Engineers in the United States, 1975 Profile. Washington, D.C.: National Academy of Sciences, 1976.

________. Commission on Human Resources. Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. Washington, D.C.: National Academy of Sciences, 1979.

National Science Foundation. Projections of Science and Engineering Doctorate Supply and Utilization 1982 and 1987. Washington, D.C.: 1979 (NSF79-303).

Radner, R. and C. V. Kuh. Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars until the Year 2000. A report to the Carnegie Council on Policy Studies in Higher Education, October 1978.

CHAPTER V

THE JOB MARKET FOR COLLEGE FACULTY*

Richard B. Freeman
Harvard University

The state of the academic job market has long received attention from academics, with committee Z of the American Association of University Professors reporting for several decades on the economic status of the profession. The sluggish growth of demand for faculty in the 1970's and anticipated decline in demand in the 1980's (Cartter, 1976) have led to more widespread concern about the academic market place, particularly with regard to the ways in which colleges and universities respond to depressed conditions.

The purpose of this paper is to examine the operation of the academic job market and evaluate the potential mode of adjustment to the changes of the 1970's and 1980's. Part I analyzes several distinctive features of the academic market and considers how they condition the process of adjustment to changes over time. Part II presents an empirical analysis of developments in the faculty market from the 1920's to the 1970's and develops a small econometric model to evaluate the effect of changes in enrollments and in the supply of potential faculty on salaries and employment.

The major finding of the paper is that the faculty job market is highly responsive to changes in the state of higher education, with salaries and employment being greatly influenced by changes in demand and supply conditions, though with some distinctive institutional peculiarities.

---

*This article represents a substantive revision and updating of "Demand for Labor in a Nonprofit Market: University Faculty" which appeared in D. Hamermesh, ed., <u>Labor in the Public and Nonprofit Sectors</u> (Princeton University Press, 1975a).

I. Characteristics of Faculty Job Market

The labor market for college and university faculty has certain distinct characteristics which affect the operation of the market place: the employing institutions are nonprofit enterprises; both employers and faculty are extremely concerned with quality issues; the internal market of colleges and universities limits variation in salaries across fields and is marked by lifetime employment contracts; the future supply of faculty is "produced" within the system; the scale of higher education depends on the demography of the population. This section analyzes the effect of each of these distinguishing characteristics of academe on the functioning of the faculty market, particularly on the responses of the system to declines in demand. It shows that, for various reasons, the faculty market is likely to be highly sensitive to exogenous "shocks," with much of the burden of adjustment falling on young faculty and potential faculty.

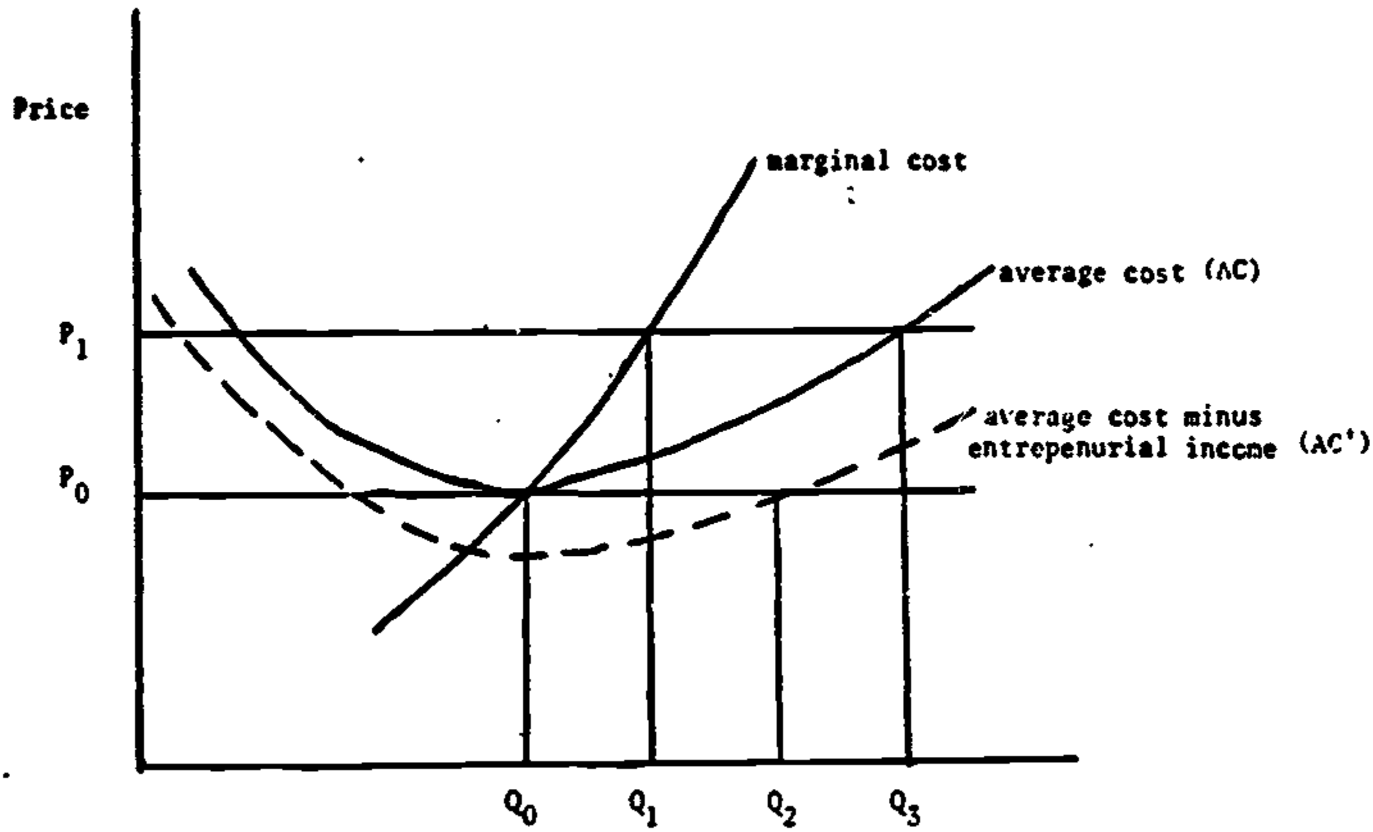
A. Nonprofit Economic Behavior

It is often asserted that nonprofit institutions, like colleges and universities, are less responsive to market conditions than comparable profit-seeking firms. The model of nonprofit behavior developed here seeks to dispel this preconception. It demonstrates that the nonprofit budget constraint, which requires that expenditures equal receipts, actually increases responsiveness to economic incentives, making employment and wages in existing institutions more responsive to market ups and downs in the short-run than would otherwise be the case; while the entry and exit of new institutions give academe and other nonprofit employers similar long-run demand curves to those of profit-seeking enterprises.

The effect of the nonprofit budget constraint on adjustments to market conditions can be most readily analyzed with the standard cost curve apparatus of price theory. In terms of cost curves, there are two distinguishing features of nonprofit enterprises. First, as Figure 5.1 shows, if the nonprofit enterprise has no required entrepreneurial return, its cost curve will lie below the curve of the comparable profit-seeking firm ($AC^1 < AC$), leading to greater output ($Q_2 > Q_0$ at price P_0) and hence

FIGURE 5.1

PRODUCTION UNOER THE ZERO-PROFIT CONSTRAINT



For-profit short-run supply curve

Nonprofit short-run supply curve

employment. Even if the nonprofit enterprise requires a normal return,[1] output will be greater in the region where profits are above normal ($P > P_0$), essentially because the nonprofit constraint requires that potential excesses of receipts over costs be spent. Second, since profits must be zero, the nonprofit firm will be governed by average rather than marginal cost considerations, at least in regions of potential profits, operating along the AC rather than MC curve.[2] But, as is obvious in Figure 5.1, the AC curve is more elastic (less steeply sloped) than the MC curve, which implies greater responses to changes in prices and costs, including faculty salaries, than would be the case under marginal cost behavior. Heuristically, when the academic market experiences a boom, colleges and universities will increase faculty employment more than would comparable profit-seeking institutions because they will spend what would have been profits on additional faculty while, conversely, in a market decline, they will reduce employment more because of the absence of a "buffer" in the form of profits.

As is demonstrated formally in Freeman (1975a), the differential elasticity of the cost curves translates into:

Proposition 1: By requiring average rather than marginal cost behavior, the nonprofit status of colleges and universities makes short-run demand for faculty more elastic with respect to wages and to shifts in enrollment than would otherwise be the case.

With a more elastic demand curve, moreover, it can be readily shown (Freeman 1975a) that:

Proposition 2: Employment of faculty should, because of the nonprofit

---

[1] It is unclear whether or not the normal entrepreneurial return is to be included as a cost of the for-profit firm, making its operation more expensive than that of the nonprofit enterprises. If entrepreneurial return is only a reward for risk-holding, and risks average out in an industry, we would not want to include it. If, on the other hand, the entrepreneurial return is a reward for "founding" an enterprise requiring future "monitoring," the "free" founding of nonprofit institutions by donors and gratis trusteeship reduce the cost of nonprofits. They face a lower price of entrepreneurship in the market as a result of their nonprofit status.

[2] Formally, where ε_A = elasticity of average; ε_M = elasticity of marginal cost curve and ε_π = elasticity of returns to scale, $\varepsilon_A = \varepsilon_M + \varepsilon_\pi$ so that $\varepsilon_\pi < 0$ due to the U-shape of the cost curve, $\varepsilon_A < \varepsilon_M$.

status of academic institutions, be more responsive to shifts in demand and supply than would be the case in a comparable for-profit market while wages should be more responsive to shifts in demand and less responsive to shifts in supply.

While the arguments and model that underlie these propositions may ignore too many features of academia to provide a useful guide to actual behavior, they make clear that, contrary to widely held opinion, non-profit status per se does not imply lack of responsiveness to market incentives.

The Subsidy Market and Budget Constraint

The importance of the nonprofit budget constraint and of subsidies as part of the constraint suggest the value of a more detailed look at those factors in the operation of colleges and universities. To begin with, Table 5.1 tabulates the receipts of all academic institutions by public and private status, respectively, in 1973. The figures show that overall, most of the revenues of colleges and universities come from governmental sources, with just 27 percent received as tuition and fees from students. Decomposed by type of institution, we see that over half of the funds of public colleges and universities (which dominate higher education) come from state governments, while by contrast, the budget of private institutions is highly dependent on tuition and fees, although nearly 20 percent is obtained from endowment and gifts.

The clearcut dependence of public institutions on public subsidization and the marked but less striking dependence of private institutions on various private subsidies suggest the value of examining in some detail the mechanism by which those subsidies are awarded to schools. The key analytic distinction is between funds "paid" for particular outputs, which can be viewed as purchase of those outputs at some price, and funds received irrespective of institutional activity.[3/]

[3/] In many cases, subsidy prices are explicit, for instance, when a state pays institutions on a per student basis.

TABLE 5.1

CURRENT FUND EDUCATIONAL AND GENERAL REVENUE
OF INSTITUTIONS OF HIGHER EDUCATION BY CONTROL, 1972-1973

	All Institutions	*Public Institutions*	*Private Institutions*
Total Educational and General Revenue	100.00	100.00	100.00
Tuition and fees	27.1	16.6	49.9
Federal government	15.4	15.0	16.1
Unrestricted	3.5	4.0	2.2
Research and other sponsored programs	11.9	11.0	13.9
State governments	35.8	51.2	2.4
Local governments	5.2	7.1	.8
Endowment earnings	2.3	.5	6.4
Private gifts and grants	5.8	2.5	13.2
Other	8.4	7.1	11.2

Source: U.S. Office of Education (1976: 222, table 115).

Subsidies awarded for particular outputs or activities establish a subsidy market where subsidizers and nonprofit firms trade dollars for goods. The supply of subsidies to the market is an upward-sloping curve linking dollars to outputs in accord with subsidizer demands for nonprofit goods. In this market, shadow prices are attached to particular outputs and are important elements in the overall price of the good, influencing employment and production decisions. The appropriate budget constraint for institutions which receive subsidies for specific output is:

$$G + tE + SE = WF + P_R R \qquad (5.1)$$

where t = tuition

S = subsidy per student

E = enrollment (assumed for simplicity to be the only output of concern)

W = wage of faculty

F = number of faculty

R = other resources

P_R = price of other resources

G = fixed receipts (endowments, etc.).

If, as Table 5.1 shows, subsidy markets are segmented with state aid going to public institutions for certain goods (number of students) and private aid to private colleges, subsidy prices will differ by source and institution. This may explain some output and behavior differences among institutions. Differential financing arrangements will, in any case, provide important clues to institutional activities and decisions. In the extreme situation of restricted or tied monies (donations for buildings, professorial chairs in American studies, etc.) there is a one-to-one correspondence of funds to inputs or outputs. If, as seems to be true, donors prefer tangible capital goods to less tangible purchases of student or faculty quality, the price of such capital will be low and buildings, stadia, etc., excessive in terms of optimal (unrestricted) budget decision-making. Physical plant may, accordingly, be "underutilized."

What is important about subsidy markets is that they make nonprofit receipts dependent on market transactions, and not, as might appear to be the case, on exogenous funding. The empirical problem in using subsidy prices to explain phenomena is the absence of explicit price data and possible confounding of differences in prices and utility functions.[4]

Fixed endowment income or other receipts unrelated to output can be expected to have a distinct effect on the price or tuition policy of institutions. When costs increase, revenues obtained from fixed sources cannot be altered, so that institutions will be forced to raise tuition by larger amounts than if all of the budget had come from variable sources. Formally, if the fixed receipts constitute B percent of the academic budget constraint, then an increase in costs of one percent should raise the price of output by (1/1-B) percent. We would expect, therefore, tuition charges to be highly responsive to faculty salaries and other costs, particularly in the private sector.[5]

<u>Entry and Exit</u>

In the long-run, demand for inputs and wage and employment adjustments depend on entry and exit conditions in an industry. If new enterprises enter whenever existing institutions have receipts above costs at the <u>minimum average cost point</u>, as occurs in competitive markets, firms will operate at the minimum point in the long-run and have factor demands appropriate to that equilibrium. If it can be argued that entry and exit of colleges and universities are governed by the possibility of average receipts above the minimum average costs, then demand for faculty <u>in the long-run</u> will be the same in academia as in a comparable for-profit market.

In higher education, the organizations that subsidize academia, notably state governments, have traditionally performed the entrepreneurial function of forming new enterprises. As long as the states seek to obtain desired output (places for students) at the lowest cost, it can be readily demonstrated that they will tend to create new colleges whenever costs rise above the minimum ($AC > \overline{AC}$) for when this occurs the subsidizers can

---

4/ While confounding could be important in comparing institutions at a point in time, time series data on, say, governmental funds can be used to infer changes in "subsidy prices" over time.

5/ Since only t changes, balancing the budget requires $\alpha_t \dot{t} = \alpha_f \dot{W}$, which leads to the possibility that increases in academic salaries could raise tuition <u>more</u> than the salary increases in percentage terms.

obtain ($1/\overline{AC}$ - $1/AC$) more output per dollar by reducing subsidies to existing institutions and using the funds to form new ones. Maximization of output per subsidy dollar and rational subsidy behavior guarantee an infinitely elastic supply of institutions (barring lumpiness) at the minimum point $\overline{AC}$. While the argument focuses on average cost as the motivating force, the particular way in which excessive costs influence behavior will depend on the institutional structure of the market. If tuition (t) is fixed (as in some state universities), shifts in the demand for education will not alter AC but rather the number of applicants rejected by universities. The resultant "shortage" of places will then motivate entry in the same manner as excessive cost in the preceding discussion. Geographic transportation and residence costs, coalescing in demands for local colleges, offer another specific impetus for new colleges and universities.

Table 5.2 examines the number of institutions in the higher education market in the period under study. It shows a striking increase in the number of colleges and universities from 1960 to 1975, when over 1,000 new educational institutions were formed, primarily by public bodies at the junior and community college level. The rapid influx of institutions suggests that the supply of public colleges and universities is very elastic with respect to the demands of students and their families and to the economic conditions underlying those demands, and thus that the long-run demand model is more relevant to changes over time than might initially be expected. While the usual arguments about sunk cost imply that exit will be a more sluggish process, there is some evidence of a marked change in the 1970's. Between 1970 and 1975, 44 colleges closed and 30 ended independent status by merger.[6/] Many states began the task of reducing proliferating graduate programs and relatively few planned on expansion of higher education. The number of institutions in the market may not fall in the late 1970's and 1980's, but it will surely not rise. Changes in numbers of programs and, to a lesser extent, in numbers of institutions are likely to play an important role in the demand for faculty in the future, as they did in the expansion of the past.

[6/] These figures were obtained from American Council on Education, Accredited Institutions of Post-Secondary Education, 1976-77 (1977).

TABLE 5.2

NUMBERS OF ACADEMIC INSTITUTIONS

	Four Year	Two Year	Total
1950	1,322	527	1,847
1960	1,447	593	2,040
1970	1,676	897	2,573
1975	1,914	1,141	3,055
Compound Annual Changes			
1950–1960	0.9	1.2	1.0
1960–1970	1.5	4.2	2.3
1970–1975	2.7	4.9	3.5

Source: American Council on Education (1976: 76, 142; 1977).

B. Quality of Inputs and Outputs

Academic concern with the quality of faculty and of institutions is likely to cause some distinctive patterns of salary and employment behavior in the market. On the demand side, concern with the average quality of faculty means that institutions must choose between numbers used and the quality of those hired, which creates distinct choice sets, along the lines set out by Houthakker's (1952-53) model. The distinctive feature of the quality-quantity interaction is that the cost of increasing the number or quality of a department depends critically on the average quality or size. Assuming concern with average quality, increases in quality are more expensive the greater the size of the department; conversely, the cost of increasing the size of faculty will depend positively on quality. The relative cost of the quality of faculty versus the number hired depends directly on the number and inversely on the quality, with definite consequences for market behavior. On the supply side, individual concern with academic quality leads to division of the market into various subgroups, with Ph.D.'s willing to take lower pay in more highly rated schools.

The critical role of quality considerations in academia has substantial implications for the market adjustment process. First, it is likely to make changes in the quality of personnel and institutions, as well as the number of appointees, important in market adjustment. When faculty wages decline due to a weak market, the types of institutions at which new Ph.D.'s obtain jobs are likely to drop while the average quality of institutional appointments rises. It is even possible that the quality adjustment will produce a perverse change in employment, as lower wages and abundant supply lead to improvements in the quality of appointees, which raises the cost of increasing numbers.[7/] While such perverse patterns are not, in fact, found in the data (see Part II), evidence on the quality of the academic institutions of first placement shows clearly that the quality of appointments is a major adjustment parameter in the market. In the late 1960's-early 1970's decline in the academic market,

[7/] Becker and Lewis (1973) consider this effect in great detail.

the proportion of new doctorates obtaining jobs outside of Cartter's "rated" universities dropped from less than one-half in 1967 to over two-thirds in 1971; the proportion in Level I or II universities was halved and, regardless of work activity, new Ph.D.'s were increasingly likely to end up in institutions of lower quality than that from which they obtained the degree (Niland, 1973).

Second, the desire of faculty to work in institutions with high average quality drives a wedge between the wages and marginal cost of hiring personnel, which may account, at least in part, for the well-known "rationing" of places in top institutions. This is because a lower quality appointment has two costs: the direct salary paid the individual and the likely increase in the salary demands of other faculty, whose work conditions will be adversely affected by their appointment. As a result, high quality schools will find it very expensive to employ lower quality faculty, while conversely, lower quality schools will have to pay enormous premia to attract the more able, leading to concentration of academic "stars" in a few places and rationing of appointments in those schools.[8/] When student concern for quality makes them willing to pay higher tuition to associate with the more able, a similar pattern in the student market is also likely. Place rationing and concentration of the more qualified in a limited number of institutions will be observed.

Third, quality considerations can be expected to play a major role in salary determination, with those judged of higher quality receiving greater pay. As is shown in Table 5.3, such a pattern is found between even as crude a measure of academic quality as articles published and individual salaries, with virtually all studies of academic salary determination finding that, other factors fixed, number of articles significantly raises earnings, constituting one of the major determinants of salary.

[8/] Since there are relatively many lower quality faculty at poorer schools, it might appear that their change in wages would more than counterbalance the increased supply price of qualified faculty, leading to dispersion of the more able. The number benefitting from high-quality colleagues may, however, be quite limited and the benefits greater for others of similar talent, producing the concentration observed in academia.

TABLE 5.3

SUMMARY OF STUDIES OF THE EFFECT OF NUMBER OF PUBLICATIONS ON ACADEMIC SALARIES

Study and Year	*Data Set*	*Controls*	*Effect of Publications Significant (√)*
Tuckman and Leahey (1975)	ACE male full-time economics faculty 1972–1973	1, 3-6, 8, (9)	√
Siegried and White (1973)	University of Wisconsin Madison, economists 1971	1, 2, 3, (5), (6), (8), (9)	√
Katz (1973)	596 faculty at single university	1, 2, 3, (5), (6), 7, (8), 9	√
Ferber (1974)	132 faculty at single university	1, (5), (6), (8), (9)	√
Freeman (1977c)	ACE sample of 3,500 whites and blacks	1, 2, (4), 6, 7, 8, (9)	√
Astin and Bayer (1972)	ACE sample of 60,000 persons	1, 2, 3, 5, 6, 7, 8, (9)	√

Note to controls

1 = years of experience
2 = administrative duties
3 = teaching productivity
4 = race
5 = department quality
6 = region
7 = quality of degree
8 = type of institution
9 = sex

( ) = controlled by focusing on group having single characteristic

C. Institutional Aspects of Academia

Turning to more specific features of the academic market, three aspects deserve attention: desire for an "equitable" wage structure which rewards faculty roughly equally across specialti s; tenure, which guarantees lifetime employment; and recent unionization.

Internal Salary Policies

That most colleges and universities would like to pay faculty of similar rank, experience, and academic ability, but different specialization, the same basic salary is evident from expressed salary goals. A 1973 Dartmouth College compensation committee, for example, stated that "since institutions constitute essential communities of scholars, there is a general feeling of what may be termed academic equity--that differences of compensation among faculty members of equal experience and standing within their own special fields should be as small as is consistent with maintenance of high-quality faculty in each department." National Education Association (1972) surveys show that nearly all institutions have explicit faculty salary schedules, providing for minimum-maximum or average pay based on merit, rank, and experience, applying equally across fields.

In essence, universities affirm an intellectual value structure that presupposes little or no inherent superiority to knowledge in various fields, in place of market valuations. According to this nonprofit "price scheme." faculty are judged by their intellectual quality and scholarly output, with differences in the market price of output (which is substantial between, say, economics and Hittite archeology) ignored as much as possible in determining wages. Underlying the rejection of market prices is the realization that valuation of knowledge involves considerable uncertainty, nonappropriability or externalities, and time horizons which may be inadequately handled by for-profit market prices.

Another factor leading to the equitable wage goal is the tendency for university administrators and members of faculty committees to come from various departments. The Dartmouth compensation committee, for example, included professors of economics, French, mathematics, and sociology, among other fields. Explicit or implicit bargaining on such committees or in administrative decision-making, with unclear standards of judgment, diverse evaluations, and similar "bargaining power," is likely to produce symmetric treatment of fields, as some game theory models would predict. When faculties are divided by schools, on the other hand, as among law, business, medicine, and arts and sciences, pressure for wage equity across disciplines will be attenuated.

Whatever the cause, the desire for interfield equity in salaries exacts a cost on the university system where nonacademic opportunity wages differ. This cost must be traded off against other goals and expenditures in the decision process. The use of resources to purchase equity in salaries will produce a narrower interfield dispersion of salaries in academia than in industry; shortages (surpluses) in specialties where opportunity wages are high (low), and reliance on compensatory nonmonetary remuneration schemes to alleviate market problems by widening the real incentive structure, despite the constraint on salaries. Such compensation policies would include differential work conditions (office space, secretarial aid), speeds of promotion, liberal outside time rules, provision of special professorial chairs, of laboratories, etc., though equity pressures may also limit these options. As such rewards are possible in the absence of the "constraint" on salaries and substitute imperfectly for flexible salaries, they will only partly alleviate the manpower problems due to the equity goal. Hiring standards are, as a consequence, likely to be an extremely important adjustment tool, with lower quality faculty employed in "shortage" fields and higher quality faculty in "surplus" areas, where job rationing will prevail.

Comparisons of the interfield structure of academic and nonacademic salaries in Table 5.4 suggest an important role of the equity goal in the market. Academic salaries turn out to be much more narrowly dispersed across fields than are industrial salaries, with a range of $3,700 versus $8,200 in the same fields and a coefficient of variation across fields of .059 in academia versus .102 in industry. More importantly in terms of adjustment processes, a similar pattern is found in comparisons of percentage

TABLE 5.4

MEDIAN ANNUAL SALARIES AND MEASURES OF DISPERSION BY FIELD, 1975

Field	*Business/Industry*	*Four Year Colleges and Universities*
Chemists	25,900	20,700
Physicists, Astronomers	25,900	22,200
Mathematicians	26,100	20,400
Statisticians	24,400	22,200
Computer Specialists	23,900	22,700
Earth Scientists	26,400	20,900
Atmospheric Scientists	22,600	23,100
Engineers	26,000	23,600
Biologists	24,900	20,400
Medical Scientists	29,900	24,100
Psychologists	30,500	20,800
Economists	30,800	22,800
Other Social Scientists	22,900	20,500
Agricultural Scientists	23,200	20,800
dispersion statistics		
range	$8,200	$3,700
standard deviation	2,650	1,288
coefficient of variation	0.102	0.059

Sources: National Science Foundation (1977: 63, table B-15).

change in salaries. From 1970 to 1975, the standard deviation of the log change of the salaries of academic doctorate scientists was .089, while the comparable industrial variation was .385.[9/] Recruitment also appears to be influenced by the interfield salary structure, as predicted by the analysis. In 1964, when the academic job market was very strong, vacancy rates in universities, defined as the ratio of unfilled budgeted positions to newly filled and unfilled slots were substantially positively correlated (r = 0.88) with the ratio of nonacademic to academic salaries in 1964 (Table 5.5). Vacancies, like high wages, are likely to attract additional specialists due to the increased probability of obtaining desirable jobs and are thus, to some extent, self-correcting.

Finally, a rigid "equitable salary" policy will alter elasticities of response to supply-demand imbalances in particular fields. Under a flexible wage regime, when a one percent change in wages clears the market in a specialty accounting for α percent of the faculty budget, average wages change by α percent while in a world of rigid wages among fields, the same adjustment requires that all salaries change by one percent--$1/\alpha$ times as great. Formally, the constraint reduces the elasticity of demand or supply in a field from say η and ε to $\alpha\eta$ and $\alpha\varepsilon$, necessitating the greater response to attain equilibrium.

Tenure

Tenure, which guarantees lifetime employment to the faculty except for reasons of institutional financial crisis or incompetency, is a much criticized feature of the academic market, though in some respects, it is quite similar to industrial seniority systems, which also protect older workers from the vagaries of the market. Both tenure and seniority result, in part, from workers' desire for job security and their willingness to forego income for seniority· both place the burden of market adjustments on the young.

[9/] The variances for 1964-1970 were calculated from salary data from the National Science Foundation, American Science Manpower (1970), table A-14, p. 84. The 1975 figures were obtained from the National Scien.. Foundation, Characteristics of Doctoral Scientists and Engineers in the U.S., 1977, table B-15, p. 63. The analysis covered all fields in Table 5.4 except engineering and other social sciences.

TABLE 5.5

THE IMPACT OF THE INTERNAL SALARY CONSTRAINT ON THE RATIO OF INDUSTRIAL TO ACADEMIC SALARIES AND ON UNFILLED OPENINGS IN UNIVERSITIES, 1964

Field	Incremental Vacancy Rate[a] (1)	Ratio of Industrial to Academic Salaries 1964 (2)	Rank of[b] (1)	(2)
Physics	0.177	1.47	1	3
Economics	0.162	1.72	2	1
Mathematics	0.143	1.65	3	2
Psychology	0.123	1.45	4	4
Chemistry	0.095	1.40	5	5
Biology	0.069	1.33	6	7
Agriculture	0.028	1.08	7	8
Geology	0.017	1.37	8	6

[a]The incremental vacancy rate is the fraction of new budgeted positions unfilled in a given year.

[b]The Spearman coefficient is 0.88. 1 percent level of significance is 0.83.

Sources National Education Association (1964); Nat'onal Science Foundation (1964).

What distinguishes tenured faculty from other senior employees is the power to hire additional faculty who do essentially the same work and could replace them on the job. It is this power which makes university departments similar to Yugoslav-type collectives, with average quality of departments rather than profits as the maximand and the quality of appointments, generally not the number, as the policy variable. In the absence of tenure, the operational problems involved in faculty hiring and firing would be immense, with each professor judging possible new colleagues as competitors who could replace him at the work place and electors deciding his future. The danger of collusive agreements, bargaining, and coalition formation seriously hampering education and research is substantial. Tenure effectively reduces such "nonproductive" behavior, making "partnership" viable in the nonprofit market where profit-and-loss sanctions are relatively inoperative, at least in the short-run.

The historical development of tenure in the U.S. lends some support to the hypothesized tenure-appointment power link, for "the growing participation of faculty in the recruitment and selecting of its own members" and "the shrinking of presidential competence" in appointments occurred roughly simultaneously with the beginning of the tenure system. It "was one of the instruments whereby university and college professors gained a nearly exclusive power to determine who was entitled to membership in their ranks."[10/] A more formal test of the tenure-appointment power link would involve examination of employment in institutions lacking tenure; deans or presidents are predicted to make hiring decisions in such educational enterprises.

Tenure, like other seniority arrangements, makes the age structure of employees and rates of expansion key parameters in market adjustments. When the higher educational system is expanding, the probability of tenure will increase above its steady-state levels: to attract additional personnel, many lower-quality faculty will be promoted and the income of those of tenure age increased relative to that of older faculty. While the number of tenure appointments increases, the proportion may remain constant or even fall, due

[10/] The developments are described in Metzger (1973), pp. 142-143.

to rapid expansion. Despite the fixed employment of tenured men, there are no difficulties in adjusting the mix of faculty to educational or research demands since expansion in fields in great demand is an adequate tool (Freeman, 1971). The 1960's were, in general, a period of this type as a result of the extraordinary demand for academic research and educational outputs.

At the opposite end of the spectrum is a period of market contraction in which tenure becomes a serious barrier to the adjustment process. In contracting markets, universities cannot readily keep on young workers of relatively high quality due to tenure commitments and have difficulty in altering the distribution of professors across disciplines to meet changing market demands. While some tools exist for removing less desirable tenured faculty, ranging from closing departments to reducing office space and related perquisites, failing to award normal salary increases or cutting salaries, and ultimately "buying out" a position, such activities are difficult in the university setting. For one thing, the academic job ladder is short, making it difficult to differentiate among permanent employees through promotion or assignment of tasks: the professor rank is the top of the ladder in particular institutions. For another, the collegial pressures needed to push men out of jobs are presumably unpleasant, especially in declining markets, and require decisions of the type tenure is designed to eliminate--those relating to the status of senior personnel.

Patterns of institutional mobility are also likely to be altered in a contracting market. In steady-state or expanding markets, it is frequent for high-quality junior faculty to "invest" several years in top institutions, where they continue their education, and then move to other colleges and universities. Contraction creates great pressures against such institutional mobility patterns, largely on the part of junior faculty outside the top schools whose promotion is threatened by importing outsiders. The risk that immediate post-degree investments in training will not bear fruit will cause more high-quality younger specialists to move outside major universities early rather than late in their careers.

When an expanding market suddenly contracts, adjustment problems are exacerbated, with tenured faculty in younger age categories and relatively small replacement demands for new appointments. Movement to a steady-state equilibrium will be extremely difficult and the entire ethos of the system unpleasant, producing--as Moynihan (1973:11) puts it--"A Balzacian society, where, if you want to be a professor, you wait until the man who is professor dies. Then the 15 of you who want the job compete in various ways. One of you gets it."

Finally, tenure probably reduces the efficiency of academics by removing the possibility of being fired for nonperformance. Those nearing retirement, in particular, may be so affected, since "compensatory firing policies"--failure to grant normal salary increases or salary cuts-- are likely to have a small effect due to the short future work life. The danger of loss of pension rights, which exists in industry, is eliminated by the vesting of academic retirement plans.

Unionism

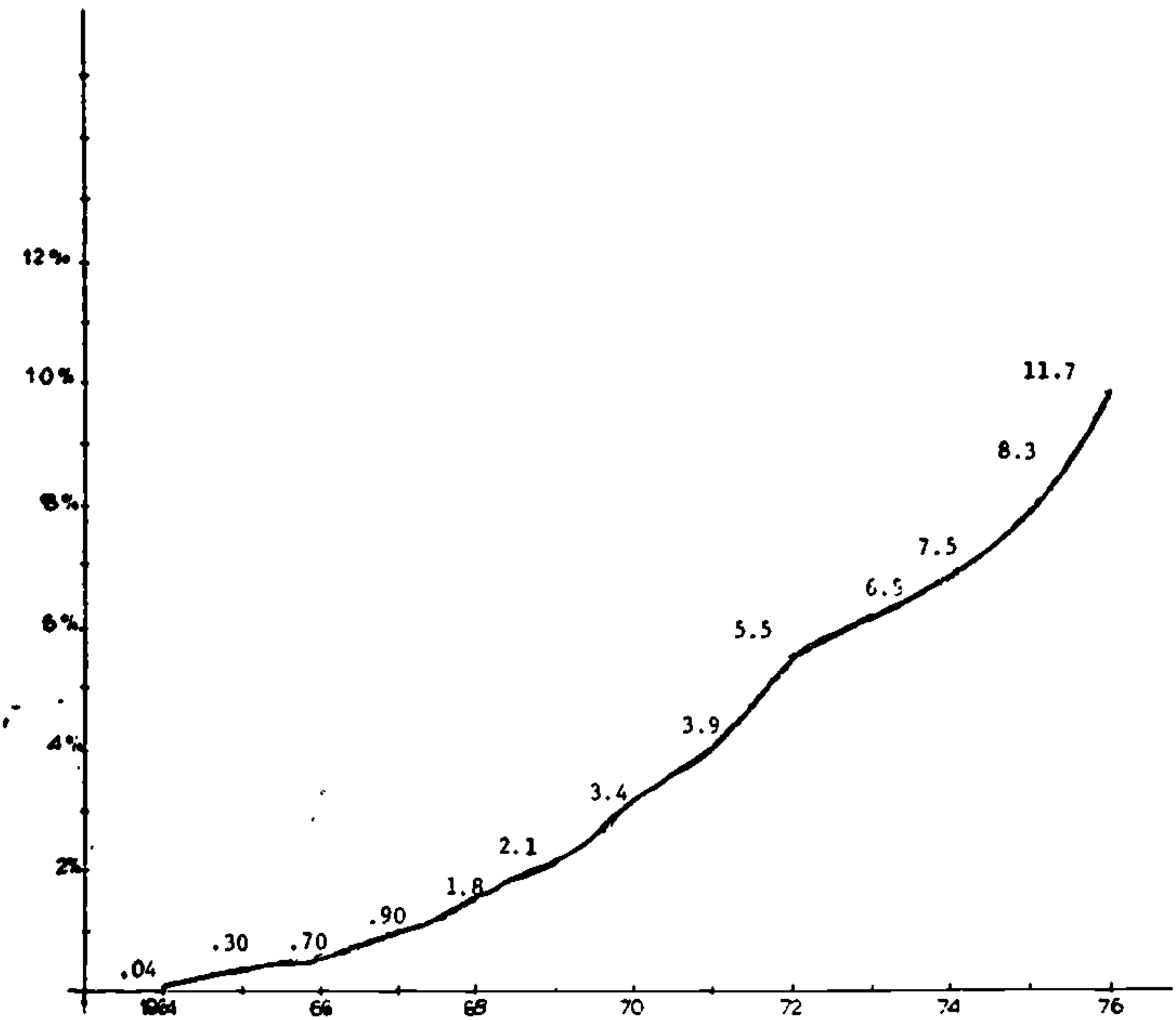
In 1965, effectively no colleges and university faculty were covered by collective bargaining contracts. In 1976, nearly 15 percent of campuses were organized (see Figure 5.2). In the brief span of a decade, organization became an important feature of the academic market place. Collective organization can be expected to affect the operation of the faculty job market in several ways. First, it may affect the salary determination process, and keep relative wages from falling as rapidly as they might in the 1980's period of declining demand. Second, and perhaps more critically, bargaining may lead to greater stress on internal labor market mobility, with existing faculty obtaining greater job security at the expense of new doctorates. Third, collective organizations can be expected to increase the fringe share of the compensation package, again to the benefit of older more experienced personnel. While faculty unionism is too new for any clear assessment of its impact on adjustment processes, it is important to bear in mind the potential differences in adjustments over time due to unionism. Comparisons of the policies of organized and unorganized institutions in the period of market decline would provide valuable insight into the impact of trade unions on the dynamics of market adjustments.

D. Capital Goods and Demographic Factors

The dependence of the demand for new faculty on changes in enrollments and the production of new faculty from graduate enrollments suggests

FIGURE 5.2

PERCENTAGE OF COLLEGES AND UNIVERSITIES
ORGANIZED BY UNIONS



Source: National Center for the Study of Collective Bargaining in Higher Education (1977); National Center for Education Statistics (1978).

application of capital goods accelerator models to the faculty market.[11/] These models highlight the dynamic adjustment problems of an industry producing and employing a long-lived capital resource such as faculty and its potential for cyclic fluctuations. Consider first the demand side of the market, which has a capital goods adjustment or accelerator structure with respect to enrollments (E) because demand for faculty depends on enrollments as well as academic salaries (W). If, as seems reasonable, faculty-student ratios are fixed save in response to changes in the real cost of faculty, demand (F^d) can be written in linear form as:

$$F^d = aE - bW \qquad (5.2)$$

where a is the parameter for enrollments and b the linear parameter reflecting responses to wages. Then, if δ is the rate at which faculty leave the system for retirement or other reasons, demand for new faculty (NF^d) will be

$$NF^d = F^d - (1-\delta)F_{-1} = aE - bW - (1-\delta)F_{-1} \qquad (5.3)$$

Equation (5.3) is a capital stock adjustment equation in which demand for new faculty depends on output, cost, and the size of the existing faculty less "depreciation." If employment of faculty was at the equilibrium level in the last period so that $F_{-1} = aE_{-1} - bW_{-1}$, equation (5.3) yields the classic accelerator model

$$NF^D = a\Delta E - b\Delta W + \delta F_{-1} \qquad (5.4)$$

which shows that demand for new faculty depends on <u>changes in enrollments</u>, changes in wages, and the rate of outflow. What is important in equation 5.4 is the ΔE term, which makes demand for new faculty critically dependent on the growth of the educational system: if, as in the early 1970's, ΔE is small, demand for new faculty will be small; if, as predicted for the 1980's, ΔE is negative, demand for new faculty may become negative. Moreover, since college and university enrollments consist largely of young persons, dependence of demand on ΔE makes the faculty market critically dependent on the age structure of the population. While in years past, the proportion of a young cohort in college was sufficiently small to provide an important buffer to demographic fluctuations, recent increases in enrollment propensities substantially limit the possible effect of such adjustments to

---

11/ See Porter (1965), Stone (1965), Tinbergen and Bos (1965) for fixed coefficient models.

future demographic declines. As a result, instability in higher education due to changes in the age structure of the population is likely to be more important in the future than in the past and deserves serious attention in public policy.

Figure 5.3 graphs log changes in enrollments from 1920 to 1976 and prospective changes (as forecast by Cartter) from 1976 to 2000. The figure shows considerable fluctuations in the change in enrollments, which implies considerable ups and downs in the market for new faculty, and makes clear the potential problem in the 1980's.

On the supply side, the fact that new faculty are "produced" by the higher educational system from graduate students leads to a more complex market. If, for simplicity, graduate training takes one period and those planning on academic careers (AG) make their decision on the basis of conditions a period prior to graduation according to an adaptive expectations process, the supply of new faculty (NF^S) can be written as:

$NF^S = AG_{-1} = \lambda\epsilon W_{-2} + (1-\lambda)NF^S_{-1}$ where ϵ is the coefficient of supply response and λ = adjustment coefficient. (5.5)

With a given parameter relating graduate students to demand (say, for simplicity a) and market clearing ($NF^S = NF^D$), equations (5.3) and (5.5) or (5.4) and (5.5) can be solved to yield a second order difference equation giving the dynamics of market adjustment to shifts in exogenous factors. With reasonable values of the parameters, the equation has complex roots that produce damped cyclic fluctuations.[12/]

[12/] To see the implications of various parameter values we solve the system. First set (5.3) equal to (5.5)

(1) $aE-bW-(1-\delta)F_{-1} = \lambda\epsilon W_{-2} + (1-\lambda)NF^S_{-1}$

Let $F_{-1} = aE_{-1} - bW_{-1}$ and $NF^S_{-1} = NF^d_{-1} = aE_{-1} - bW_{-1} - (1-\delta)F_{-2}$ and substitute to obtain

(2) $aE-bW - (1-\delta)(aE_{-1} - bW_{-1}) = \lambda\epsilon W_{-2} + (1-\lambda)$
$[aE_{-1} - bW_{-1} - (1-\delta)aE_{-2} + (1-\delta)bW_{-2}]$

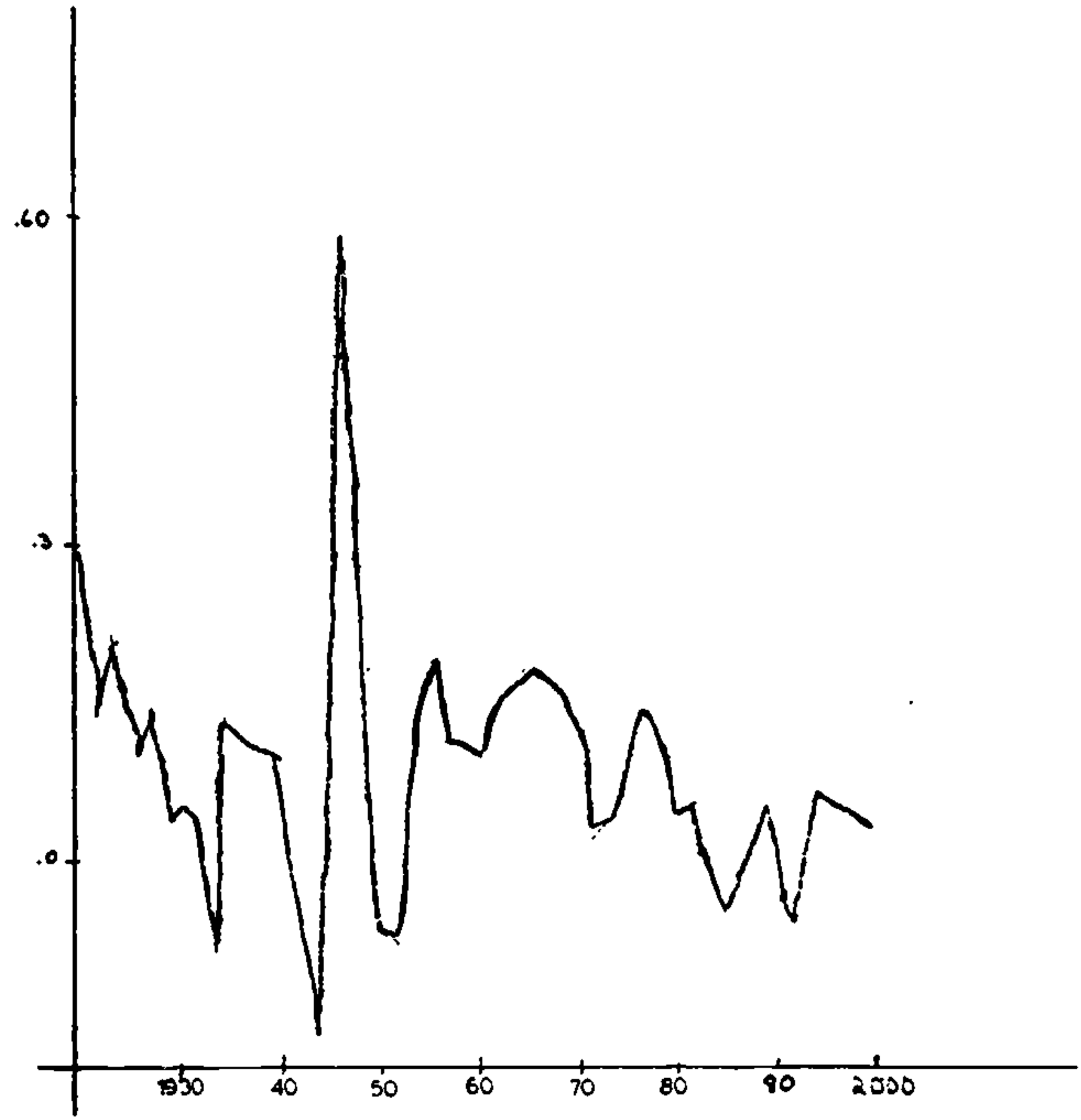
Focusing on the adjustment of dW we have the following

(3) $-bW = -(1-\delta)bW_{-1} + \lambda\epsilon W_{-2} - (1-\lambda)bW_{-1} + (1-\lambda)(1-\delta)bW_{-2} + X$

where X represents all non-W terms (continued on p. 110)

FIGURE 5.3

LOG CHANGES FOR ENROLLMENT 1920-76
AND PREDICTED CHANGE 1976-2000



Source: 1920-76 U.S. Bureau of Census, Historical Statistics of the U.S., series H 321 updated with U.S. Office of Education (1977), table 3.03, p. 177.

1976-2000, Cartter (1976), table 4-9, p. 58 with C-series used.

The cycle will be longer than the cobweb cycle in the labor market because demand as well as supply is influenced by enrollment decisions of students. A typical scenario for the cycle would be: on the demand side, high academic salaries ⟶ increased graduate enrollments ⟶ greater demand for faculty ⟶ higher salaries, a response pattern tending to explosive movements; and on the supply side, high academic salaries ⟶ increased graduate enrollments ⟶ increased supply of new Ph.D.'s ⟶ increased supply of faculty ⟶ decrease in academic salaries, the usual cobweb adjustment process. The demand-side cycle is attenuated when graduate students are used as teachers, for the demand increasing effect of graduate enrollments is reduced and possibly reversed. Investigation of this aspect of the market requires analyses of the substitutability between faculty and graduate teaching assistants and consideration of their relative salaries or costs.

The significance of the endogeneous cyclic mechanism in the faculty market will differ across fields, depending on the relative importance of faculty used to produce faculty. When undergraduate enrollment or graduate enrollments independent of the faculty market account for the bulk of academic demand--as in engineering, for example--fluctuations in the faculty market will be proportionately small. When, on the other hand, graduate students loom large in enrollments and tend primarily to become teachers, as in the more arcane subjects, fluctuations could be suostantial until equilibrium is attained.

12/ This can be rewritten as

(4) $W = (2-\lambda-\delta)W_{-1} - [\lambda\frac{\varepsilon}{b} + (1-\lambda)(1-\delta)]W_{-2} + X$

A reasonable value for the supply adjustment parameter (λ) is 1/2; a reasonable value for the outflow of faculty (δ) is 1/20. Since ε refers to the supply response of new Ph.D.'s and b to <u>total</u> faculty demand, $\varepsilon/b \leq 1$ because the ratio of new Ph.D.'s to total faculty is perhaps 1 to 20, so that even if the supply of new Ph.D.'s were 10 times as elastic as demand, ε/b would be at most 1/2. Taking ε/c as 1/2, we obtain

(5) $W = 1.45W_{-1} - .73W_{-2} + X$

which yields imaginary roots with dampened oscillations (since the coefficient on W_{-2} is less than 1) and $(1.45)^2 < 4(.73)$.

Summary

The principal theme of this part of the study is that the academic job market is likely to be, for various reasons, a highly responsive allocative mechanism, though one operating under certain well-defined institutional and structural constraints. The nonprofit status of colleges and universities and the capital goods/accelerator structure of the market are likely to produce sizeable adjustments and fluctuations in the face of changing conditions. The internal salary structure, tenure system, and concern for quality are likely to create distinct forms of adjustment, along the lines developed herein.

II. Econometric Analysis of Faculty Market Developments

This section turns from the factors that condition the operation of the academic market place to the observed pattern of responsiveness. It examines the major developments in the market in the 1950's, 1960's, and 1970's and then estimates a small econometric model of employment and salary determination that can be used to assess past and predict likely future responses to changes in market conditions.

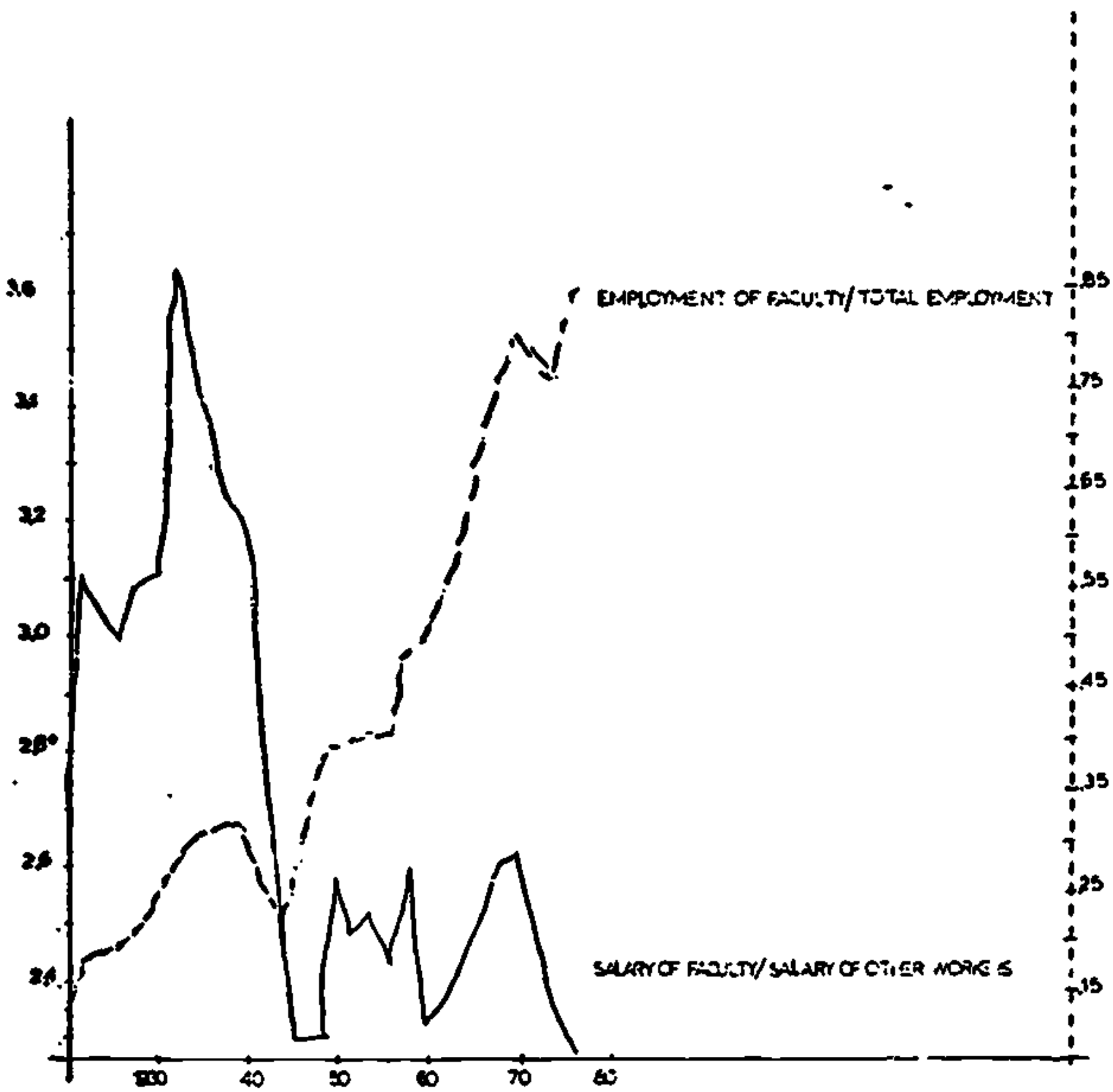
A. Market Developments

The changing economic position of faculty over the long-run is examined graphically in Figure 5.4, which records the ratio of faculty salary to industrial earnings, and the ratio of faculty to nonagricultural employment.[13/] The figure reveals considerable variation in the state of the market over time, presumably in response to changing economic conditions. Relative faculty compensation increased steadily in the 1920's, after declining during World War II; peaked in 1932 due to slow adjustment to depression conditions; and then declined to a minimum of 2.4 : 1 in 1956. From the mid-1950's until the late 1960's, academic salaries rose compared to other salaries, as the higher education system entered what has been called a "golden age" of expansion. By contrast, in the late 1960's and 1970's, the relative gains of the preceding decade were eroded as the market underwent a major turnaround.

[13/] The data are obtained from American Council on Education, A Fact Book on Higher Education (2nd issue, 1976) tables 76.102, 76.108, 76.111, 76.114.

FIGURE 5.4

RELATIVE SALARY AND EMPLOYMENT OF FACULTY



Sources: 1920-1976, U.S. Bureau of Census (Various) and U.S. Office of Education (1977: 177, table 3.03. 1976-2000, Cartter (1976: 58, table 4-9, with C series used).

The relative employment figures show an upward trend in academic employment, with varying rates over time. There were large increases in the number of faculty per worker in the mid-1950's and in the 1960's, following World War II, and at the outset of the Depression when the number of faculty held steady while total employment dropped sharply. During World War II and the Korean War period, the ratio of faculty to total employment dropped. From 1970 to 1974 the ratio also dropped, presumably as part of the turnaround, but then rose in 1976.

Additional data from the decennial Census of Population and annual Current Population Survey can be used to examine the growth of faculty relative to other professions requiring considerable education. The ratios of faculty to other professional employment from the Census (Table 5.6) show a pattern similar to that in Figure 5.2, with, however, a more modest trend in post-World War II years due to the professionalization of the work force and a more marked slowdown in the 1970's.

Sixties Boom and Seventies Bust

The pattern of change in the 1960's and 1970's, when the market went from boom to bust, deserves more detailed analysis.

During the boom period, the higher education system enjoyed the benefit of an unprecedented increase in the number of college age (18-24 year old) persons of 8 million from 1960 to 1970 (U.S. Bureau of the Census, 1972) which together with a high rate of return to college produced an extraordinary growth of enrollments of 4.8 million students or 126 percent over the decade (U.S. Office of Education, 1977, p. 177). Coincident with this expansion, the receipts of higher educational institutions increased rapidly, tripling from 1960-1961 to 1968-1969 (O'Neil, 1971; Office of Education, 1972). Total federal aid to academia, including diverse direct student support, facilities, and equipment purchases rose rapidly. The price of education to students, in the form of tuition per full-time equivalent enrollment unadjusted for student aid, declined modestly relative to that of the 1950's, while public tuition and fees increased more slowly than private charges, raising the ratio of private to public tuition from 4.0 in 1960 to 4.7 in 1970.

TABLE 5.6

RELATIVE NUMBER OF FACULTY

	1900	*1910*	*1920*	*1930*	*1940*	*1950*	*1960*	*1970*	*1976*
College faculty/ all professional	0.006	0.009	0.014	0.019	0.020	0.025	0.024	0.043	0.042
College faculty/ engineers	0.184	0.208	0.246	0.286	0.259	0.234	0.205	0.395	0.451
College faculty/ lawyers	0.065	0.139	0.268	0.385	0.423	0.690	0.840	1.784	1.300
College faculty/ teachers	0.016	0.027	0.044	0.059	0.071	0.111	0.106	0.178	0.173

Sources: U.S. Bureau of the Census, *Historical Statistics of the U.S.* (1977: 1, ser. D-233-682, 140-41) and *Census of Population* (1970: Occupational Characteristics P(2)-7A, 1-2, table 1); U.S. Department of Labor (1975: 186, table A-53).

On the supply side, the major development was the enormous inflow of new Ph.D. and master's degree graduates, which substantially augmented the population of potential faculty (National Research Council, Annual; U.S. Office of Education, 1972). Between 1960 and 1970, the number of Ph.D. degree recipients tripled; the ratio of new Ph.D.'s to enrolled students rose 36 percent; and the total stock of Ph.D.'s increased by 80 percent.

Toward the end of the 1960's and in the 1970's, the forces underlying the higher educational boom began to level off or decline. The demographic growth in the number of persons of college age came to an end: in 1970, there were 24.7 million 18-24 year olds; in 1975, 27.6 million (U.S. Office of Education, 1977, p. 146). With the rate of return to college dropping (Freeman, 1976, 1977a) the proportion enrolled also fell, with a consequent stabilization or reduced rate of increase in college enrollments, depending on the data and group covered. According to the Office of Education (1977), total enrollments increased from 1970 to 1976 at an annual rate of 5.3 percent compared to an 8.5 percent rate from 1960 to 1970; first year degree credit enrollment grew by 1.5 percent per year from 1970 to 1975 compared to 6.8 percent per year in the previous decade; the rate of increase in graduate enrollments decelerated from the 12.6 percent per year of the 1960's to 4.1 percent in the 1970-75 period. According to the U.S. Bureau of Census (1977, p. 5), total college enrollments grew by 5.0 percent per annum from 1970 to 1976, while freshman enrollments grew by only 2.9 percent per annum compared to rates nearly twice as high in the previous decade. In several scientific fields, such as physics, first year graduate enrollments fell sharply despite the increased number of bachelor's graduates from which to draw students (Freeman, 1975b). Federal support for graduate education and research declined in importance and total income of colleges and universities grew relatively slowly, with the ratio of spending of higher education to GNP barely changing from 1970 to 1976 after having nearly doubled in the previous decade.[14/] The supply of

[14/] The ratio of expenditures to GNP in 1960 was .013; in 1970, .025; in 1976, .029. Data on GNP from U.S. Department of Labor, Employment and Training Report of the President 1977, table G-3, p. 283. Data on expenditures from U.S. Office of Education, The Condition of Education 1977, volume three, part one, table 3.08, p. 181.

job candidates grew rapidly, as the large classes of graduate students drawn into the market in the 1960's graduated and sought work. With demand leveling off and supply growing, the job market for faculty experienced a sharp slump, which showed up in salaries and employment.

The pattern of change in salaries in the period is examined in Table 5.7, which compares the rate of change in real (1976 dollars) salaries from 1969-70 to 1975-76 to the changes from 1960-61 to 1969-70. The table tells a clear story about salary adjustments to the changed market. From 1960-61 to 1969-70, academic salaries increased in real terms at a more rapid pace than other salaries, so that the ratio of academic compensation to average annual earnings in industry rose from 2.28 to 2.50. From 1969 to 1976 by contrast, academic salaries fell in real terms and relative to other wages and salaries: the ratio of academic compensation to average annual earnings in industry was 2.20 in 1976, below the level at the outset of the 1960's boom.

With respect to employment, the rate of growth of faculty dropped, as can be seen in Figure 5.2 and Table 5.6. From fall 1970 to fall 1976, U.S. Office of Education data (1977, table 2.04, p. 178) show an increase in the number of faculty of 3.1 percent per annum compared to an increase of 7.6 percent per annum from 1960 to 1976, while Bureau of the Census data show a drop in the rate from 10.7 percent per annum in the 1960's to 1.3 percent from 1970 to 1976.[15/] The slow growth of faculty had a marked depressant effect on the employment prospects of young academics and greatly altered the age structure of the faculty. Among new Ph.D.'s there was a sharp decline in the proportion obtaining academic jobs readily. In 1970, approximately 59 percent of new doctorates had definite prospects in academia upon receipt of their degree; in 1975, just 47 percent were in such a position.[16/] As noted earlier, the type of job held by those getting jobs in academia also underwent institutional deterioration in this period,

---

[15/] The Census data are from U.S. Bureau of the Census, Current Population Reports, Series P-20.

[16/] Tabulated from National Academy of Sciences, National Research Council, Annual Survey of new Ph.D.'s.

TABLE 5.7

ACADEMIC SALARIES IN PERIODS OF MARKET BOOM AND BUST

	Academic and Other Salaries 1960–1976 (in 1976 dollars)			*Compound Annual Change in Salaries*	
	1960–1961	*1969–1970*	*1975–1976*	*1960–1969*	*1969–1975*
Professors					
(1) total compensation	20,964	28,089	26,576	3.3	−1.0
(2) salaries	19,554	25,327	23,233	2 9	−1.4
university	22,518	27,114	24,590	1.0	−1.6
public	–	26,455	24,150	–	−1.5
private	–	29,598	26,540	–	−1.8
junior colleges	17,272	23,031	22,136	3.2	−1.6
(3) salaries NEA	19,388	24,448	22,218	2.6	−1.6
Assistant Professors					
(4) total compensation	13,367	17,717	16,487	3.2	−1.2
(5) salaries	12,620	16,057	14,336	2.7	−1.9
university	13,567	16,273	14,670	2.0	−1.7
public	–	16,310	14,690	–	−1.7
private	–	16,289	14,740	–	−1.7
junior colleges	13,533	16,229	15,080	2.0	−1.2
(6) salaries NEA	13,043	15,595	14,069	2.0	−1.7
Other Workers[a]					
(7) annual compensation, industry	9,123	11,243	12,073[b]	2.1	1.1
(8) manufacturing, average hourly wage	4.39	5.20	5.19	1.9	−0.1

[a] Data for other workers relate to the initial year of academic year.

[b] Extrapolated 1974 by rate of change in manufacturing hourly wage from 1974 to 1976.

Sources: Lines 1, 2, 4, 5: American Association of University Professors (1960-1978).
Lines 3, 6: National Education Association (Biennial).
Lines 7, 8: U.S. Department of Commerce (1977), and U.S. Department of Labor (1977).

with an increasing number obtaining work in lower quality institutions. The drop in new hires shows up dramatically in the data on the age and rank structure of science faculty in Table 5.8. In 1968, 42 percent of the science faculty had received their Ph.D. within seven years, in 1974, just 29 percent. In 1970, 64 percent of the faculty were full or associate professors, in 1975, 71 percent. After decreasing for about a decade, the median age of faculty rose sharply in the 1970's. Lack of job opportunities for new Ph.D.'s became one of the major problems facing higher education. In terms of the theoretic considerations of Part I, the problem reflects both the capital stock/acceleration aspect of demand and the tenure system.

Not surprisingly, in view of the evidence of the career responses of young persons, the market decline appears to have affected graduate enrollments substantially. In the areas most severely affected by the turnaround, notably physics, enrollments fell at astounding rates. Between 1965 and 1972, first year graduate enrollments in physics declined by 33 percent; in other physical sciences, the decline in enrollments was more moderate but nonetheless striking in view of past trends and the growing number of baccalaureates.[17/] Many major universities embarked on policies to reduce graduate classes or, at the least, to warn entering students of potential market problems (see Figure 5.5).

All told, the salary, employment, and supply adjustments of the late 1960's and early 1970's produced a market for faculty that differed drastically from that of the preceding golden age.

B. An Econometric Model

The response of the faculty market to the 1960's boom, the turnaround, and earlier economic conditions can fruitfully be analyzed with a small econometric model of employment and salary determination. Unlike most education-sector models (Cartter, 1971; Porter, 1965), which assume fixed faculty student ratios, the model allows for demand adjustments to changes in academic salaries and the interrelation between employment and salary determination. Its principal outputs are estimates of long-term elasticities of demand and of the responses of employment to exogenous market developments.

[17/] See Freeman (1975b) for a detailed analysis of the response of physics to the market turnaround.

TABLE 5.8

CHANGES IN THE EXPERIENCE AND RANK DISTRIBUTION OF DOCTORATE SCIENCE FACULTY, 1968-1975

	Percentage of Doctorate Faculty With Seven or Less Years Since Doctorate			*Percentage of Doctorate Faculty at Professor or Associate Professor Level*		
	1968	*1974*	*Change 1968–1974*	*1970*	*1975*	*Change 1970–1975*
All	42.1	29.4	−12.7	64.4	71.4	7.0
Physics	31.6	18.5	−21.1	60.3	77.1	16.8
Chemistry	34.9	21.4	−13.5	61.5	74.7	13.2
Mathematics	51.9	36.8	−15.1	57.4	67.4	10.0
Economics	42.7	37.4	−5.3	72.1	73.8	1.7
Psychology	43.8	38.7	−5.6	62.2	68.5	6.3

Sources: U.S. National Science Foundation (1968: 10, table 2; 1974: 20, table B-1; 1970: 189-190, table A44; 1975: 110, tables B, B-25).

FIGURE 5.5

STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305

DEPARTMENT OF ENGLISH

March 11, 1977

I am delighted to inform you that the Graduate Admissions Committee has approved your application for admission to the Department of English next fall.

I enclose a description of our fellowships. I hope you will find it informative. However, it is basically an explanation of departmental policy and does not represent a commitment on the part of the university *per se*. Such commitments are made by the Dean of the Graduate Division, who will contact you by mail on or about March 15 in order to present the university's formal offer.

Before entering this, or any other, Ph.D. program in English, you should understand that the prospects for permanent employment after you have earned the Ph.D. are generally poor. As a Department, we work extremely hard at placing our graduates, and they may expect to compete favorably for whatever jobs are available; but we do not anticipate that there will be many openings in the forseeable future. Anyone who chooses to pursue a career in college teaching these days is taking a large risk. Please keep this fact in mind as you weigh your own alternatives.

We think highly of our departmental program, and the fact that we have singled you out of several hundred candidates obviously means that we think highly of you.

You have, as you know, until April 15 to accept the offer. Because we also have a duty to the highly qualified applicants on our waiting list, it would be helpful to us if we could hear from you sooner, however.

Again, congratulations. We look forward to seeing you in September.

Sincerely yours,

David R. Riggs
Director of Graduate Admissions

DRR/da

Enclosure

The key equation in the model is the long-run demand for faculty, which will be written in log form as dependent on enrollments and wages:

$$FAC^D = -\eta SAL + ENR + \mu_1 \qquad (5.6)$$

where the capital letters refer to the natural logs of the variables and where FAC^D = number of faculty demanded, SAL = salary, ENR = enrollment, and μ_1 = random disturbance. The unit coefficient on ENR implies that the faculty-student ratio is fixed except when salaries change.

Actual changes in faculty (FAC) employment can be assumed to move toward the long-run according to the standard partial adjustment model

$$\Delta FAC = \lambda(FAC^D - FAC_{-1}) \qquad (5.7)$$

which, substituting for FAC^D, yields

$$FAC = -\lambda\eta SAL + \lambda ENR + (1-\lambda)\ FAC_{-1} + \mu_1 \qquad (5.8)$$

as the relevant estimating equation. In (5.8), the long-term elasticities are obtained by using the coefficient on FAC_{-1} to obtain λ and dividing into the other coefficients.

On the supply side, the supply of faculty FAC^S will be taken to depend on the number of persons "available" to teach and on salaries in academia and in alternatives (ASAL)

$$FAC^S = \epsilon SAL - aASAL + bSTK + \mu_2 = \epsilon SAL - aASAL + b_1 FAC_{-1} \qquad (5.9)$$
$$+ b_2 PHD + \mu_2$$

where STK = estimated number of potential faculty

PHD = number of new Ph.D. graduates in the period

μ_2 = random error

The estimated potential supply (STK) will be calculated as the sum of the number of faculty in the previous period less an estimate of "depreciation" plus the number of Ph.D.'s interested in teaching. Changes in the outflow of experienced faculty or in the willingness of new Ph.D.'s to teach due to changing market conditions are captured in the responses to SAL and ASAL.

If salaries are assumed to clear the market in each period, (5.9) can be combined with (5.6) or (5.8) to yield "reduced form" equations for salaries and employment. Setting FAC^D in (5.6) equal to FAC^S in (5.9) yields:

$$FAC = (\varepsilon/\varepsilon+\eta)ENR + (\eta/\varepsilon+\eta)(-aASAL + bSTK) + \mu_2 \quad (5.10)$$

$$SAL = (1/\varepsilon+\eta)(ENR + aASAL - bSTK) + \mu_3 \quad (5.11)$$

with (5.8) as the demand equation, an additional FAC_{-1} term enters both equations.

If, as seems reasonable, salaries do not adjust sufficiently rapidly to clear the market in each period, it is necessary to add a salary adjustment equation to the system. One possible adjustment equation postulates that salaries move along a partial adjustment path, toward the market clearing level:

$$\Delta SAL = \psi(SAL^{*}-SAL_{-1}) \quad (5.12)$$

where SAL^{*} is the long-term equilibrium as determined by SAL in (5.11). Substituting (5.11) into (5.12) yields the estimating equation:

$$SAL = (\psi/\varepsilon+\eta)(ENR + aASAL-bSTK) + (1-\psi)(SAL_{-1}) + \mu_4 \quad (5.13)$$

An alternative potential salary adjustment model is to make changes depend on the deviation between actual and desired levels of employment:

$$SAL = \phi_1\left[FAC^{D}_{-1} - FAC\right] + \phi_2\left[FAC - FAC^{S}_{-1}\right] \quad (5.14)$$

where FAC^{D}_{-1} - FAC represents the difference between employment demanded at the initial wage and current employment and FAC - FAC^{S}_{-1} is the difference between employment and the long-term level of supply at the existing wage. Since salaries will rise when demand exceeds current levels of employment and when employment exceeds long-term supply, ϕ_1 and $\phi_2 > 0$.

Substituting and simplifying, we obtain the following estimating equation

$$SAL = \phi_1 ENR + a\,\phi_2 ASAL + (\phi_2-\phi_1)FAC + (1-\phi_1\eta-\phi_2\varepsilon)\,SAL_{-1} + \mu_5 \quad (5.15)$$

Since ϕ_1 is the coefficient that weights the demand influence on salaries and ϕ_2 the coefficient that weights supply influences, if (as seems likely), demand factors are more important in salary determination, $\phi_2 < \phi_1$, and the coefficient on FAC will be negative. If supply factors are more important, the converse will be true. Because economists lack an adequate theory of salary or price adjustments (Arrow, 1959) there are other possible ways in which to model the salary adjustment process and in which to interpret the resultant coefficients. Since, in general, the various models have similar basic structures, with lagged salary terms picking up the effect of the past, I will not develop alternatives in this paper but instead focus on estimates of (5.13) and (5.15).

Given partial adjustment equations (5.8) and (5.13) or (5.15) the reduced form of the model can be written in the following matrix form

$$\begin{matrix} FAC \\ SAL \end{matrix} = A(X) + B \begin{matrix} FAC_{-1} \\ SAL_{-1} \end{matrix} \qquad (5.16)$$

where A and B are matrices of reduced form coefficients and X is a column vector of exogenous variables (ENR, ASAL, and PHD). This equation highlights the interrelated adjustment of employment and salaries in the market, with lagged values of each affecting the other. To obtain the long-term impact of the X's on FAC or SAL, it is necessary to solve the matrix equation

$$\begin{matrix} FAC \\ SAL \end{matrix} = (I-B)^{-1} A(X) \qquad (5.17)$$

Because the supply of Ph.D. graduates is taken as exogenous in the model, it does not provide a "full" long-term equilibrium but rather yields employment and salary relations conditional on number of Ph.D.'s. The economic factors that influence the supply of Ph.D.'s have been examined in detail elsewhere (Freeman, 1971, 1975b, 1977b; Center for Policy Alternatives, 1977) and are not pursued here.

Table 5.9 presents estimates of the demand for faculty equation (5.8) and variants thereof for the period 1920-1976 using the data described in detail in the source note. The calculations in lines 1-4 relate log faculty to the salaries of assistant professors on the hypothesis that demand is more responsive to the pay of younger nontenured than of older faculty, while line 5 uses the salary of full professors as the relevant cost variable. Both variables are deflated by the Consumer Price Index (CPI) to remove the effect of inflation.[18/] Because of sharp abnormal jumps in the period surrounding World War II, the years 1944-1948 are deleted from regressions 1-3 and 5. To make sure that this deletion is not critical to results, line 4 covers the entire period. The calculations are limited to even-numbered numbers (ending academic year) due to data availability.

[18/] A more appropriate but unavailable deflator would be the price of output of institutions, including subsidy prices.

TABLE 5.9

ESTIMATES OF DEMAND FOR FACULTY, 1920-1976

Regression and Technique	Constant	SAL	SAL (−1)	ENR	ENR (−1)	FAC (−1)	R^2	D.W.
1. OLS	6.4	−0.13 (0.12)	−0.15 (0.10)	0.74 (0.10)	0.31 (0.11)		0.998	0.76
2. OLS	3.3		−0.18 (0.06)	0.52 (0.08)		0.53 (0.08)	0.999	1.30
3. IV	6.3	−0.20 (0.12)		0.58 (0.10)		0.47 (0.10)	0.998	1.37
4. OLS[b]	3.2		−0.20 (0.06)	0.50 (0.05)		0.58 (0.06)	0.998	1.81
5. OLS[c]	3.2		−0.16[c] (0.07)	0.48 (0.08)		0.56 (0.09)	0.999	1.21

[a]Dependent variable is log Faculty (*FAC*); independent variables also in log form; numbers in parentheses are standard errors; D.W. = Durbin Watson statistic; OLS = ordinary least squares; IV = instrumental variables: lagged variables and log Ph.D. as instruments; period covered excludes 1944-1948, except in line 4. Salary variable is salary of assistant professors deflated by C.P.I. except in line 5; observations covered are even-numbered years.

[b]Covers entire period including 1942-1948.

[c]Salary variable is salary of full professors deflated by C.P.I., period 1942-1948 excluded.

Sources: *FAC* = total instructional staff, from U.S. Bureau of the Census (Various: Series H317, 210); U.S. Office of Education (1974-1977: 178, table 3.04 in volume 3); *ENR* = total degree credit enrollment, from same sources (Series H321, 210, table 3.03). *SAL* = salary of assistant (full) professors.

The main finding in Table 5.9 is that demand for faculty responds to changes in academic salaries with a small but reasonably well-specified elasticity and with some lag. In equation 1, which links faculty employment to the real salary of assistant professors and total enrollments in the current and precedent (two years previous) period, the elasticity with respect to the sum of the two salary variables is -.28, while the coefficients on enrollment run to the expected unity (1.05). Addition of of lagged employment of faculty essentially eliminates the effect of current salaries and lagged enrollments, leading to equation 2, which relates employment to salaries two years earlier, enrollment, and lagged faculty. In this equation, the long-run elasticity of demand is -.38 (= -.18/(1-.53)),[19/] somewhat larger than in the first regressions. In line 3, the lagged salary variable is replaced by current salaries, instrumented for simultaneity on lagged salaries, number of Ph.D. graduates (in log form) and the other variables in the equation, with similar results. Here the short-run elasticity is -.20 and the long-run elasticity is -.38. Addition of the deleted years 1944-48 in line 4 gives the same short-run elasticity and a somewhat higher long-run elasticity (-.44), indicating that despite the obvious differential developments in those years, the results do not hinge on a particular subset of observations. When the salary of assistant professors is replaced by the salary of full professors in line 5, the results are also comparable, in part because the salaries of the two groups move together. Enrollments obtain a coefficient of about unity in all of the calculations, supporting the notion of a fixed faculty-student ratio, cost incentives held fixed. In short, the evidence indicates a long-term elasticity of demand with respect to salaries of -.28 to -.44 and of unity with respect to enrollments, and suggests an adjustment process in which demand responds to past salaries and current enrollments with a partial adjustment parameter of about one-half.

A similar set of findings is given in the salary regressions of Table 5.10 which record estimates of equations (5.13) and (5.15) with STK calculated

---

[19/] The long-term equilibria are obtained from the partial adjustment model

$$\Delta X = \lambda X^* - X(-1)]$$

where ΔX is the change in the variable, X^* is the desired equilibrium level, $X(-1)$ is the previous level, and λ is the partial adjustment parameter.

TABLE 5.10

ESTIMATES OF ALTERNATIVE SALARY DETERMINATION EQUATIONS FOR ACADEMIC FACULTY, 1920-1976

Constant	*ENR*	*ALT*[b]	*STK*[c]	*FAC*	*SAL (−1)*	R^2	*D.W.*
1. 3.0[d]	0.20 (0.13)	0.66 (0.11)	−0.36 (0.13)		0.36 (0.09)	0.972	1.14
2. 5.2[d]	0.53 (0.20)	0.72 (0.11)		−0.69 (0.21)	0.22 (0.09)	0.975	1.21
3. 3.5[e]	0.14 (0.11)	0.66 (0.10)	−0.26 (0.12)		0.25 (0.09)	0.979	1.09
4. 5.0[e]	0.35 (0.17)	0.71 (0.10)		−0.48 (0.18)	0.16 (0.08)	0.981	1.22

[a]Dependent variable is log salary (*SAL*) of faculty, with salaries of assistant professors used in lines 1 and 2 and salaries of full professors in lines 3 and 4, both deflated by C.P.I. Independent variables in log form. Period covered excludes 1944-1948. Numbers in parentheses are standard errors; D.W. = Durbin-Watson statistic. All estimates by ordinary least squares.

[b]*ALT* = salary of school teachers from U.S. Bureau of Census (Various: Series D728) and from U.S. Office of Education (1972) with 1976 estimated using percent change in average hourly earnings for production workers.

[c]*STK* estimated as log of [0.97 × absolute number of faculty in previous period + 0.70 × number or Ph.D.s graduated in current and precedent year]. This assumes a 3 percent outflow and that 70 percent of new Ph.D.s would on average desire to teach.

[d]Assistant professors salary.

[e]Full professors salary.

Sources: U.S. National Science Foundation (1968: 10, table 2; 1974: 20, table B-1; 1970: 189-190, table A44; 1975: 110, tables B, B-25) with Ph.D.s obtained from U.S. National Academy of Sciences (Annual).

as described in the table note and with FAC entered separately. Alternative salaries (ALT) are measured by the salary of high school teachers. While teaching in secondary schools is a significant option for many faculty, especially at the junior and community college levels, the variable was chosen primarily because it is the only professional income series covering the entire 1920-1976 period.[20] Lines 1 and 2 of the table relate the salaries of assistant professors to the estimated stock of faculty, enrollment and alternative salaries while lines 3 and 4 deal with the salaries of full professors. In all of the calculations, the explanatory variables obtain correctly signed and generally significant coefficients of reasonable magnitude. According to line 1, for example, an 11 percent increase in enrollment raises salaries by .2 percent in the short-run and by .3 percent in the long-run; increases in alternative earnings have larger positive effects; while the "stock" of available academics reduces salaries with an elasticity of -.36 in the short-run and -.56 in the long-run. The effect of current faculty size in line 2 is even larger, -.69, providing strong evidence of what may be called a demand tradeoff between employment and earnings. Not surprisingly, perhaps, the effect of the available supply or current employment on the salaries of full professors in lines 3 and 4 is estimated to be much smaller, with long-run effects of -.35 (line 3) and -.57 (line 4).

In all of the lagged-adjustment regressions of Table 5.10, the estimated adjustment parameter (one minus the coefficient in SAL(-1)) is larger than in the corresponding employment regression of Table 5.9. This implies a more rapid response of salaries than of employment to market conditions, which may reflect the importance of tenure on employment adjustments and the key role of quality adjustment in academia.

The way in which faculty employment and salaries are affected by shifts in demand and supply schedules is examined in Table 5.11 by least squares estimation of the reduced form of the model of (5.15). Shifts in demand are

---

[20] National Education Association (1965) data reveal that in academic year 1963-64 and 1964-65, 17 percent of all new academic hires and one-third of those in two-year institutions come from secondary school teaching.

TABLE 5.11

REDUCED FORM ESTIMATES OF THE DETERMINANTS OF
SALARY AND EMPLOYMENT OF FACULTY, 1920-1976

	Independent Variable	Coefficients on	
		SAL	FAC
1.	ENR	0.12 (0.15)	0.54 (0.09)
2.	ALT	0.74 (0.13)	0.05 (0.08)
3.	Ph.D.	−0.12 (0.11)	0.06 (0.07)
4.	FAC (−1)	−0.17 (0.24)	0.39 (0.14)
5.	SAL (−1)	0.40 (0.10)	−0.21 (0.06)
6. Summary statistics			
	R^2	0.974	0.999
	SEE	0.051	0.030
	D.W.	1.06	1.43
7. Long-run elasticities[b]			
	ALT	1.31	−0.29
	Ph.D.	−0.26	0.17
	ENR	−0.12	0.94

[a]Dependent variables are deflated salary of assistant professors and total number of faculty. Independent variables are in 1n form. Numbers in parentheses are standard errors; D.W. = Durbin-Watson statistic; years covered exclude 1942-1948.

[b]Calculated by solving equation $\begin{pmatrix} SAL \\ FAC \end{pmatrix} = (I-A)^{-1} BX$

where A is the matrix of coefficients on SAL (−1) and FAC (−1).

Sources: U.S. National Science Foundation (1968: 10, table 2; 1974: 20, table B-1; 1970: 189-190, table A44; 1975: 110, tables B, B-25); U.S. Bureau of the Census (Various) and U.S. Office of Education (1974-1977).

measured by enrollments and alternative salaries by the pay of high school teachers as in previous computations. Because FAC_{-1} enters into the reduced form separately, the STK variable (which consists primarily of FAC(-1)) is replaced by log Ph.D.'s.

The regression results provide general support for the applicability of the model to the faculty market and suggest considerable responsiveness of employment and salaries to exogenous developments. Consistent with preceding estimates, alternative earning opportunities and enrollment raise salaries of academics while the number of Ph.D.'s reduces salaries, as does the lagged number of faculty. The only anomalous coefficient is the effect of alternatives on faculty employment, which is positive rather than negative, as might be expected. Because of the interaction between salaries and employment in both equations, however, this does not necessarily translate into anomalous long-run effects, for the long-run impact of the exogenous factors depends on the interrelation between employment and salaries, as specified by equation (5.17).

Line 7 presents the results of solving the system to obtain the desired long-term impact coefficients: in the full solution, alternative earnings raise salaries and lower employment, as they should, while the number of Ph.D.'s has the opposite effect. Here, however, another anomaly arises: while enrollments have a large positive effect on faculty employment, they are estimated to reduce rather than raise salaries, though by a relatively small amount.

While the computations in Tables 5.9-5.11 provide general support for the notion that the academic market place responds in economically sensible ways to exogenous shocks, they suffer, it should be stressed, from several weaknesses. First and most importantly, many of the features of the market place discussed in Part I have been deleted from consideration in order to make use of limited available quantitative data. Second, econometric issues (serial correlation of residuals, simultaneity, possible correlation of residuals across equations, lines of causality) have not been seriously examined, in part because previous work (Freeman, 1975a) has found the basic results impervious to these issues. Third, alternative models,--for instance, a detailed autoregressive moving average procedure--have not been estimated as a means of testing the robustness of the findings. The basic data are too weak to merit such analysis. What they show is an inverse relation between academic employment and salaries and a link between those variables and the supply side of the system, which is at least roughly consistent with the notion of a flexible labor market.

III. Conclusions

This study has examined the operation of the faculty job market from the perspectives of the theory of derived demand, the institutional characteristics of academia, and a simple econometric model of demand and salary adjustment. The paper has emphasized that demand for faculty is responsive to changes in the cost of employment, albeit with peculiarities due to nonprofit motivation and the distinct features of higher education. It has argued that the nonprofit nature of colleges and universities increases responsiveness in the short-run while entry and exit conditions of institutions are likely to produce long-run demand behavior similar to that in profit markets. According to the analysis, concern for quality in academia may produce complex interactions between the number and quality of workers, which are likely to lead to greater quality than quantity adjustments, rationing of places in high-level institutions, and a concentration of the most qualified in a limited number of universities. The "equitable" wage goal of universities, to reward comparable faculty similarly regardless of nonacademic opportunities, substantially narrows the interfield wage structure, producing less dispersion than in other sectors of the economy. Equitable wage policies exact a cost in terms of flexibility of response to market changes and are likely to be loosened in times of financial difficulties.

Tenure also reduces the responsiveness of the higher education system, particularly in periods of market decline when expansion of faculty cannot be used to reallocate resources across disciplines. Issues of academic freedom aside, tenure is critical in a system where senior employees control appointments. Internal production of faculty and the lag structure in producing Ph.D.'s create an accelerator-type adjustment process with long dampened cyclic fluctuations. As increasing proportions of cohorts enroll in college, the system becomes especially sensitive to the number of persons of college age.

The empirical analysis in Part II has shown that the faculty market has indeed undergone considerable fluctuations, indicative of a highly responsive labor market. The most important change in the market was the termination of the "golden age" of the 1960's toward the end of that decade. With research and related expenditures no longer increasing, enrollments leveling off, and the number of Ph.D.'s seeking work increasing as a result of previous market conditions, the academic marketplace underwent a significant turnaround. Real salaries dropped from 1969 to 1976, employment conditions worsened, and new Ph.D.'s were forced to take less prestigious jobs. The age structure of the faculty changed dramatically, with the proportion less than 30 years old declining significantly in the period. The econometric estimates lend support to the basic argument of a responsive market, though one subject to lagged adjustments. The elasticity of demand for faculty was estimated to be -.3 to -.5 while salaries were found to be substantively influenced by supply and demand forces.

REFERENCES

American Council on Education. Accredited Institutions of Post-Secondary Education, 1976-77. Washington, D.C.: Council on Post-Secondary Accreditation, 1977.

_______. A Fact Book of Higher Education. Washington, D.C., 1976-77.

Arrow, K. Toward a Theory of Price Adjustment. In M. Abramovitez, ed., The Allocation of Resources. Stanford: Stanford University Press, 1959.

Astin, H. S. and A. E. Bayer. Sex Discrimination in Academe. Educational Record, 53: 101-18, 1972.

Becker, G. and H. G. Lewis. On the Interaction Between the Quantity and Quality of Children. Journal of Political Economy, 81: S279-88, 1973.

Cartter, A. Science Manpower for 1970-1985. Science, 172: 132-40, 1971.

_______. Ph.D.s and the Academic Labor Market. New York: McGraw Hill, 1976.

Center for Policy Alternatives. Improved Methodologies for Forecasting the Supply of Scientists and Engineers. Cambridge, Massachusetts: Massachusetts Institute of Technology, 1977.

Ferber, M. A. Professors, Performance and Rewards. Industrial Relations, 13: 69-77, 1974.

Freeman, R. B. Market for College-Trained Manpower. Cambridge, Massachusetts: Harvard University Press, 1971.

_______. Demand for Labor in a Nonprofit Market: University Faculty. In Daniel S. Hamermesh, ed., Labor in the Public and Nonprofit Sectors. Princeton: Princeton University Press, 1975a.

_______. Supply and Salary Adjustments to the Changing Science Manpower Market: Physics, 1948-1973. American Economic Review, 65: 27-39, 1975b.

_______. The Overeducated American. New York: Academic Press, 1976.

_______. The Decline in Economic Rewards to College. Review of Economics and Statistics, 59: 18-29, 1977a.

_______. Employment Opportunities and Doctorate Manpower. Mimeograph Report to National Academy of Sciences. Washington, D.C., 1977b.

______. The New Job Market for Black Academicians. Industrial and Labor Relations Review 3, No. 2 (January): 616-74, 1977c.

Houthakker, H. Compensated Changes in Quantities and Qualities Consumed. Review of Economic Studies, 19: 155-64, 1952-53.

Katz, D. A. Faculty Salaries, Promotion, and Productivity at a Large University. American Economic Review, 63: 469-77, 1973.

Metzger, W. Academic Tenure in America: A Historical Essay. In Commission on Academic Tenure in Higher Education, Faculty Tenure. San Francisco: Jossey-Bass, 1973.

Moynihan, D. "Peace"--Some Thoughts on the 1960s and 1970s. The Public Interest, 32: 3-12, 1973.

National Education Association. Salaries in Higher Education Continue to Grow. Washington, D.C.: National Education Association Research Division, 1965.

______. Faculty Salary Schedules in Colleges and Universities. Washington, D.C., Report 1972.

National Research Council. Summary Report 1975: Doctorate Recipients from United States Universities. Washington, D.C.: National Academy of Sciences, 1975.

National Science Foundation. American Science Manpower. Washington, D.C.: U.S. Government Printing Office, 1970.

______. Characteristics of Doctoral Scientists and Engineers in the United States. Washington, D.C.: U.S. Government Printing Office, 1976-77.

Niland, J. Where Have All the Ph.D.'s Been Going? Ithaca, New York: Cornell University, 1973.

O'Neil, H. Resource Use in Higher Education. Berkeley, California: Carnegie Commission, 1971.

Porter, R. C. A Growth Model Forecast of Faculty Size and Salaries in U.S. Higher Education. Review of Economics and Statistics, 47: 191-97, 1965.

Siegfried, J. J. and K. J. White. Financial Rewards to Research and Teaching: A Case Study of Academic Economists. American Economic Review, 63: 309-15, 1973.

Stone, R. A Model of the Educational System. Minerva (London), 3: 172-86, 1965.

Tinbergen, J. and H. Bos. Econometric Models of Education. Paris: O.E.C.D., 1965.

Tuckman, H. P. and H. Keahey. What is an Article Worth. Journal of Political Economy, 83: 951-68, 1975.

United States Bureau of the Census. Occupational Characteristics. Washington, D.C.: U.S. Government Printing Office, 1963.

______. Census of the Population. Washington, D.C.: U.S. Government Printing Office, 1970.

______. Historical Statistics of the United States Statistical Abstract. Washington, D.C.: U.S. Government Printing Office, 1972.

______. Current Population Survey, Series P-20. Annual. Washington, D.C.: U.S. Government Printing Office, 1977.

United States Department of Labor. Employment and Training Report of the President. Washington, D.C.: U.S. Government Printing Office, 1975.

United States Office of Education. Digest of Educational Statistics. Washington, D.C.: U.S. Government Printing Office, 1972.

______. The Condition of Education. Washington, D.C.: U.S. Government Printing Office, 1974-77.

______. Digest of Educational Statistics. Washington, D.C.: U.S. Governnment Printing Office, 1977.

CHAPTER VI

PROSPECTS FOR YOUNG FACULTY IN PHYSICS AND OTHER SCIENCE AND ENGINEERING FIELDS TO 1990

Lee Grodzins
Massachusetts Institute of Technology

There is well-founded concern for the continued vitality of science and engineering faculties. Many studies are showing that faculties are aging, becoming more tenured, with fewer and fewer opportunities for hiring new blood. Atelsek and Gomberg (1979), in particular, showed that in the past four years, the faculties in the nineteen fields surveyed grew but one percent per year while the percentage of young faculty declined by several percent per year.

This paper reports on two studies directed at estimating the future magnitude of these developments and the appropriate size of programs to counteract them. The first study, described in Part I below, reports projections of demand for physics and astronomy faculty based on a four-tiered model (Professor, Associate Professor, Assistant Professor and Instructor). The parameters of this model are derived from census data on Ph.D. physicists for the years 1959-1979 which appear in the Directories of Physics and Astronomy Faculties in North American Colleges and Universities published annually by the American Institute of Physics (AIP). In Part II of the paper, we use a simplified two-tier version of this model (senior and junior faculty) based on less complete data to extend these results to science and engineering faculties as a whole and to some specific scientific fields. The simplified two-tiered model is also used to estimate the size of an "add-on scholars" program needed to reverse the projected declines in hiring of young faculty. We conclude in Part III that modest programs, which phase out toward the end of the decade when retirement rates become substantial, can result in a more desirable, more stable situation in which the percentage of young scholars is not less than 20 percent and there is an adequate infusion per year of these young scholars into tenure track positions.

1. Projected Demand for Physics and Astronomy Faculty, 1978-1990

In earlier studies (Grodzins, 1979a, 1979b), we have shown that the declining supply of doctoral physicists for the physics labor market is reaching an asymptotic level of about 800 per year* and that dramatic changes in composition in physics departments over the last two decades were not accompanied by major changes in promotion policies, in years spent at a given rank, or in relative hiring into different ranks. The data implied that the changing composition could be understood in terms of a single model with but one variable, the total size of the faculty. Here, we will test these observations and show that the compositional changes can indeed be understood on the basis of changes in the total faculty size in physics. The model calculations will then be extrapolated to 1990; variations in the parameters show the effect of changing the number of years spent at a given rank, promotion percentages, the overall growth rates, etc. At the end of Part 1, we will combine these forecasts with our earlier supply projections to predict the odds that numbers of a given Ph.D. class who enter the physics labor force will be absorbed into a doctoral-granting physics department in succeeding years.

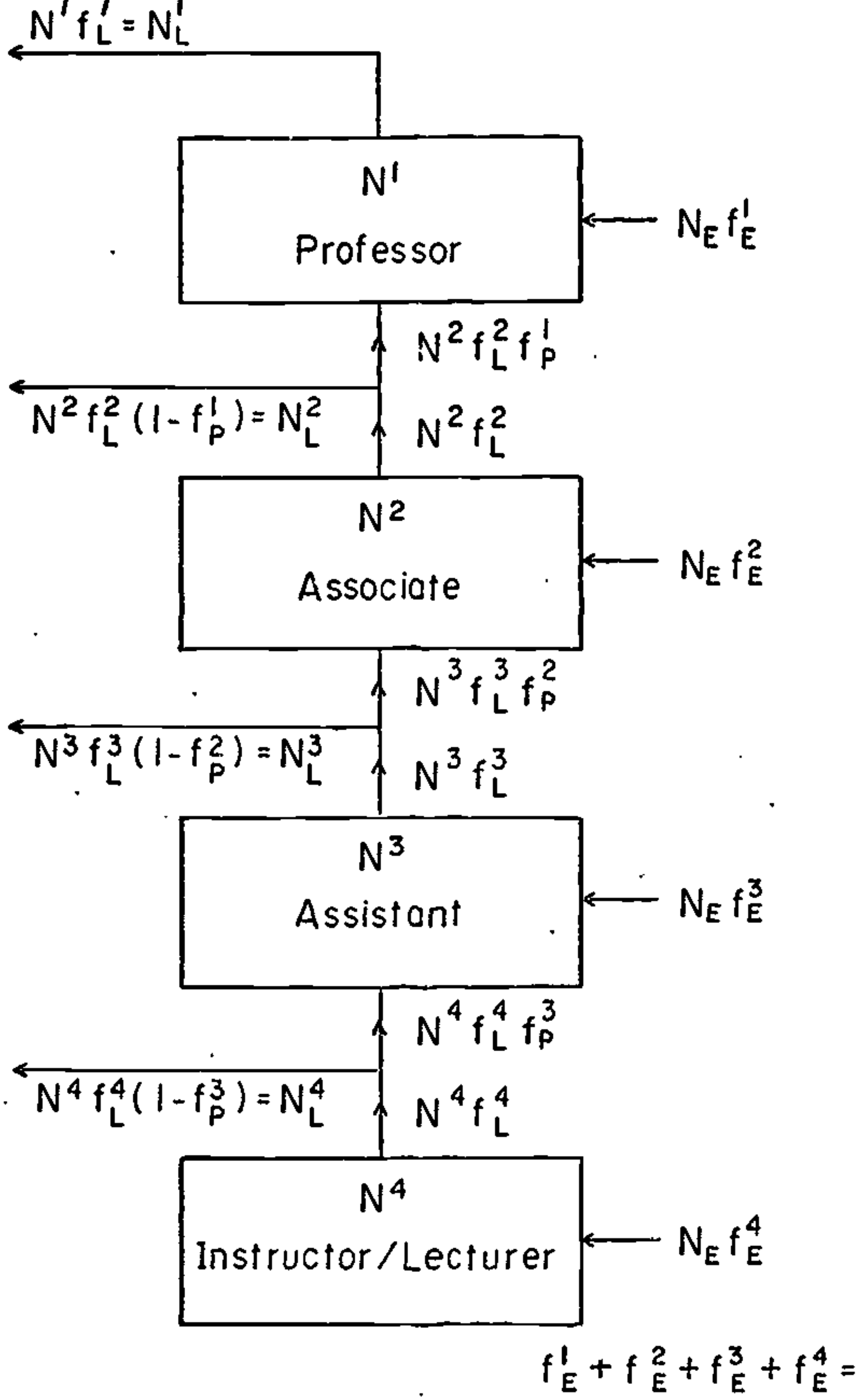
The Model

The model we will use is shown diagramatically in Figure 6.1. The rank of Professor, Associate, Assistant, Instructor-Lecturer, is designated by the superscript 1,2,3. and 4 respectively. The number of professors at a time (t) is therefore $N^{1}(T)$; $N_{Tot}(T)$ is the total number of faculty.

The fraction of a given rank (j) that leaves that rank each year will be called F_L^j. The inverses of these fractions are the average times that the average faculty member spends in the respective ranks. This parameter does not distinguish between those promoted in the department, those pulled from the department to take positions elsewhere, or those who are forced to leave because their contracts were not renewed.

Of those who leave a given rank, a certain fraction are promoted in the same department. We will call that fraction F_p^j; promotion to rank j.

*The value of 800 assumes that the foreign graduate students on temporary visas do not enter the labor market.



A FOUR-TIERED MODEL OF FACULTY FLOWS

FIGURE 6.1

The F_p fractions do not include those who transfer to another department with promotion; neither do they include the few cases each year of faculty who make double jumps and even triple jumps of promotion.

The fraction of the new hires that enter into the various ranks will be designated as F_E^j. These fractions include all those who enter from outside the department, whether they have or have not come from academia.

The input/output equations for this simple model are then given by the following equations:

$$N^1(T+1) = N^1(T) + N^2(T)\ F_L^2\ F_P^1 + N_E(T+1)F_E^1$$

$$N^2(T+1) = N^2(T) + N^3(T)\ F_L^3\ F_P^2 - N^2F_L^2 + N_E(T+1)F_E^2$$

$$N^3(T+1) = N^3(T) + N^4(T)\ F_L^4\ F_P^3 - N^3F_L^3 + N_E(T+1)F_E^3$$

$$N^4(T+1) = N^4(T) - N^4F_4^4 + N_E(T+1)F_E^4$$

$$F_E^1 + F_E^2 + F_E^3 + F_E^4 = 1$$

$$N_E(T+1) = N_L^1\ (T) + N_L^2\ (T) + N_L^3\ (T) + N_L^4\ (T) + CN_{\text{Total}}\ (T)$$

The fraction C is the fractional change of the total faculty in adjacent years.

The program is initialized by giving the faculty sizes N^j and values for the eleven parameters F_L^j, F_P^j, and F_E^j. With the parameters fixed, the only variable is C. The usefulness of the model is measured by its ability to replicate, over a period of time, the distributions of faculty ranks and the numbers per year who are promoted and leave. The calculations were carried out on a programable calculator whose power was insufficient to make a systematic variation of parameters in order to optimize the fit. It was quite easy, however, to find a consistent set which gave satisfactory results in explaining historical data on faculty flows (see Grodzins, 1979b).

The faculty distributions for the "best" sets of parameters are shown in Figures 6.2 and 6.3 for the 100 oldest departments and for the ten private school departments respectively. Comparing these distributions with the actual ones (reported in Grodzins, 1979b) shows that the difference between the model calculations and the actual figures are generally less than 10 percent.

FIGURE 6.2

Model Calculation of Faculty Distribution in 100 PhD Granting Departments in U.S.

	I	II	III
% Prof. Leave	4	4	4
% Assoc. Leave	14.3	14.3	14.3
% Prom. Prof.	80	85	80
% Asst. Leave	25	25	25
% Prom. Assoc.	53.5	50	53.5
% Inst. Leave	50	50	35
% Prom. Asst.	20	28	25
% Hired Prof.	10	16	16
% Hired Assoc.	11	5	11
% Hired Asst.	40	55	59
% Hired Inst.	39	24	14

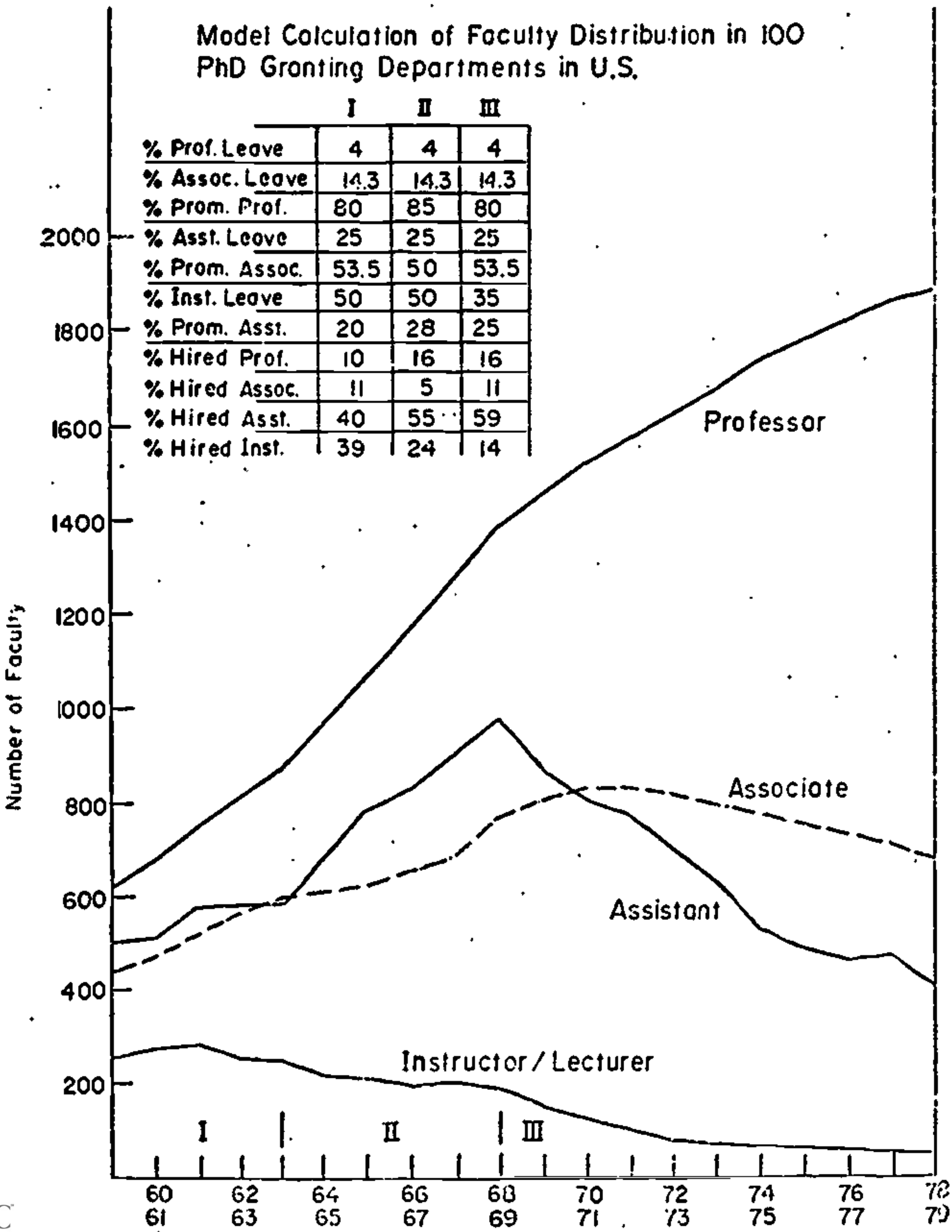
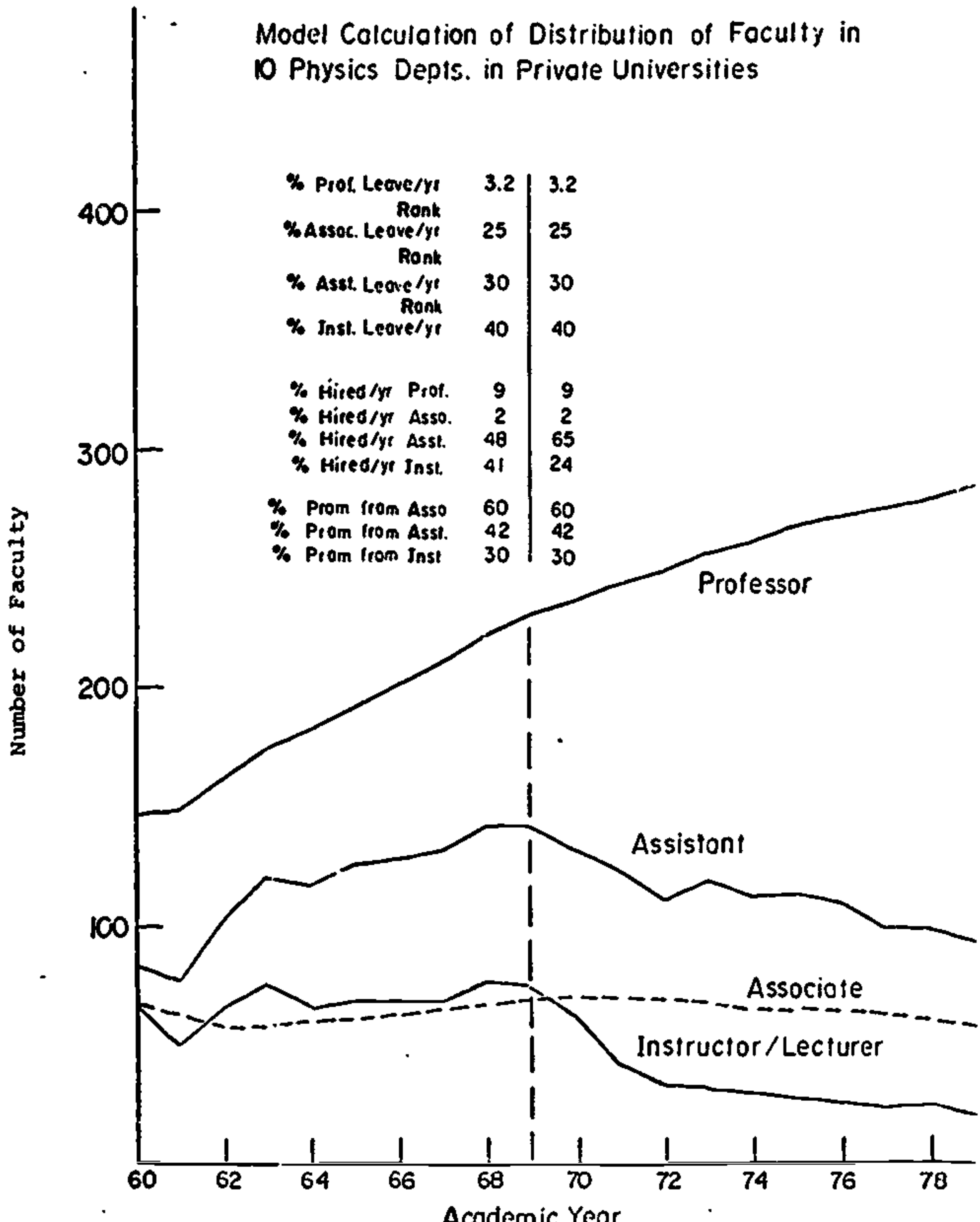


FIGURE 6.3


Model Calculation of Distribution of Faculty in
10 Physics Depts. in Private Universities
% Prof. Leave/yr Rank 3.2 3.2
% Assoc. Leave/yr Rank 25 25
% Asst. Leave/yr Rank 30 30
% Inst. Leave/yr 40 40
% Hired/yr Prof. 9 9
% Hired/yr Asso. 2 2
% Hired/yr Asst. 48 65
% Hired/yr Inst. 41 24
% Prom from Asso 60 60
% Prom from Asst. 42 42
% Prom from Inst 30 30
Professor
Assistant
Associate
Instructor/Lecturer
Number of Faculty
400
300
200
100
60
62
64
66
68
70
72
74
76
78
Academic Year

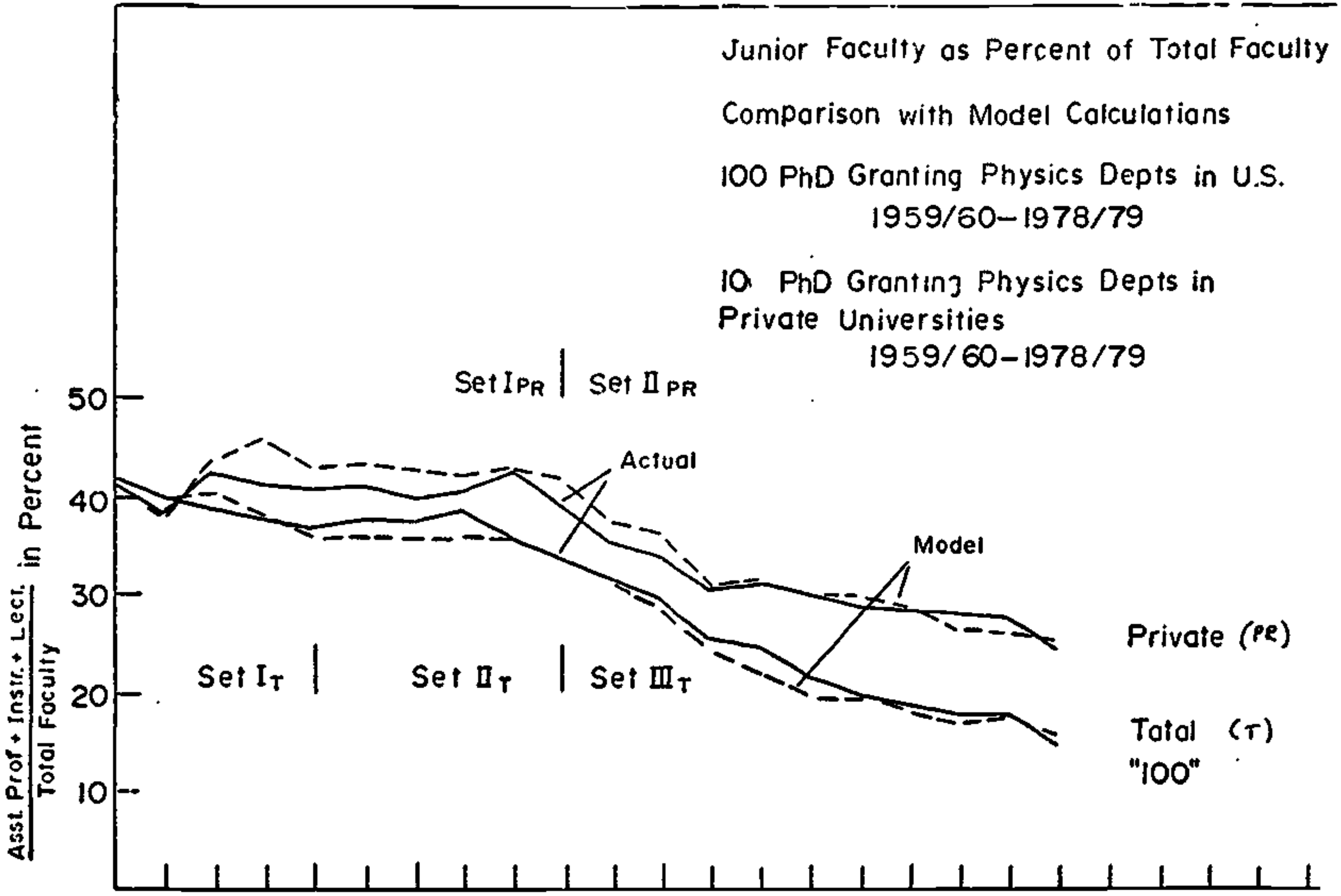
Three similar sets of parameters, covering different periods, were needed to obtain the fit for the 100 older departments; only two sets were needed to obtain the fits for the private institutions. We consider each in turn.

In the 100 older departments, the numbers in the Instructor-Lecturer rank began to decline around 1963-64. Around 1968, the drop became precipitous as hiring into this rank halved. Only one set of parameters is needed to obtain an acceptable fit to the changes in the distribution of faculty ranks from 1968. The set chosen is not optimum and a single set is not unique; the effects of small changes in one parameter, such as years in the Instructor rank, can be compensated by changes in another parameter, such as the number hired in the Instructor rank. A decrease in the average time spent at the Associate (or Professor) ranks results in an increase in the size of the Assistant Professor rank at the expense of the Associate (or Professor) rank since hiring is mainly into the junior faculty positions.

A decrease in promotion percentages from the Assistant to Associate Professor ranks also increases the number of Assistant Professors at the expense of the Associate ranks. The percentage of junior faculty increases and so too does the number of new hires, but the latter group flows through the system without "sticking" - - that is, the actual number absorbed into tenure positions does not rise.

Increases in the percentage hired at the lower ranks also increases the sizes of the junior faculties but decreases the proportion absorbed.

In Figure 6.4 we show how well the model calculations duplicate the actual percentage of junior faculty for the 100 older schools and the ten private institutions. The private schools consistently have higher percentages of young faculty since the average "sticking" fraction of new hires is lower than for public universities; on the average these ten schools promote only 35 percent of those leaving the rank of Assistant Professor versus almost 55 percent for the public institutions. The value of 35 percent promotion has a very broad spread: some schools promote only one in six of their Assistant Professors while other schools, equally prestigious, promote more than half. Examining the records of



JUNIOR FACULTY AS PERCENTAGE OF TOTAL FACULTY:
COMPARISON OF ACTUAL AND MODEL CALCULATIONS

FIGURE 6.4

each of these ten schools over the period from 1959 on indicates that each school has maintained its own tradition of hiring and promotion practices with little change over 20 years. We expect that this observation is general; there is undoubtedly great variation in promotion and hiring practices from department to department but an individual department maintains a consistent practice over a long period of time.

Atelsek and Gomberg (1979) have tabulated the F_h^1 factors expected by physics departments for the 1978-79 academic year. The numbers from their survey are listed in Table 6.1 along with the actual parameters and the model parameters for the 1977-78 to 1978-79 transitions. The differences are not great; the sets of parameters are quite consistent with each other.

Before taking up the consequences of this model, we wish to emphasize, if it is not abundantly clear, how simplistic it is. There are no feedback loops. In this model the composition of the faculty is neither determined by the availability of the supply of potential professors nor by the need to carry out certain academic duties such as teaching or research, except insofar as the patterns were historically established by each department in order to best carry out its varied functions. In light of the consistency of the trends over the past 20 years, it seems reasonable to assume that the parameters which departments can control (promotions and hiring percentages, as well as the average time spent in the junior ranks) will not be much affected by educational or marketplace forces. There are, however, parameters which are so affected and which could have substantial impact on the number of young faculty brought in each year.

Most important is the fraction of the Professors who leave each year. Death plus retirement are expected only to deplete the Professors rank by at most two percent per year. The actual rate of depletions of this tenured rank has been one and one-half to two times higher. We do not have much follow-up information of where these faculty, who neither retire nor die, go, but we do know that some take administrative positions in academia while others take administrative positions in research laboratories in government and in industry. Some leave to start their own businesses and others leave the country, generally to return to their country of origin. Incentives for early retirement would tend to increase the numbers leaving the tenured ranks, counteracting the increase in the statutory retirement age which has taken place in the past year.

TABLE 6.1

A COMPARISON OF PARAMETERS AFFECTING FACULTY CHANGES FROM 1977/1978 TO 1978/79 ACADEMIC YEAR
(DOCTORAL GRANTING PHYSICS DEPARTMENTS)

		Percentage of Hires				Percentage of Those Leaving Rank of				Percentage of Those Leaving Rank Who Are Promoted to		
	Total Hires	Prof.	Assoc.	Asst.	Inst./ Lect.	Prof.	Assoc.	Asst.	Inst./ Lect.	Prof.	Assoc.	Asst.
(1) 196 Physics and Astronomy Departments	235	12.8%	18.7%	55.3%	13.2%	2.5%	11.6%	26.4%	40.6%	77.1%	57.2%	12.1%
(2) 100 "Oldest" Physics Departments	136	12.5	17.0	55.9	14.7	2.5	12.7	25.3	38.1	80.2	55.4	32.0
(3) HEPR Survey, 1978-79 (expected) 156 Departments	220	13.4	10.7	59.7	16.1							
(4) HEPR Survey, 1978-79 (expected), Private Schools, 51 Departments	71	8.8	5.3	73.7	12.3							
(5) Model Calculations "Best" 1968-79 Parameters		16.0	11.0	59.0	14.0	4.0	14.3	25.0	35.0	80.0	53.0	25.0
(6) Model Calculations "Best" 1968-79 Parameters (Private)		9.0	2.0	65.0	23.0	3.2	25.0	30.0	40.0	60.0	42.0	30.0

Source: (1) and (2), AIP Directories of Physics and Astronomy Faculties in North America; (3) and (4), Atelsek and Gomberg, 1979; (5) and (6), Model Calculations

The distribution by ranks of new hires is obviously at the control of the departments, but the percentage of new hires that are young is already high and all departments will have needs for hiring some new faculty at the senior levels. The overall growth rate of faculty is the single most important parameter affecting the department composition. Throughout the 1980's, the number of college-age students will decline, falling to about 12.5 million students in the ages between 18 and 21 by the year 1995. While this decline may have an important effect on aggregate enrollment, there seems to be no compelling reason why it should affect the number of faculty in most of the doctoral-granting schools. Almost all of them are sought-after universities that turn away well-qualified applicants. Through the 1980's, these universities may have to broaden their criteria for acceptance in order to maintain their student body size, but the changes in admissions criteria are not likely to be major and the disciplines which the students will pursue are not likely to be less oriented toward sciences in the 1980's than they have been in the past. Physics teachers are needed primarily to teach the service load courses. We expect that that load will be largely independent of the total student enrollments. We, therefore, consider both positive and negative growth rates in the following section.

Model Calculations of the Faculty Distributions in Physics Until 1990

The simple model described above has been used to determine faculty compositions, the percentage of junior faculty, and the hiring at the junior levels for various parameter sets extrapolated to 1990. In Figure 6.5, these calculations are plotted for the 100 oldest departments as a function of total faculty growth rates; "best" model parameters are used. In Figure 6.6, for the 100 oldest physics departments, we show the dramatic effects on junior faculty if average retirement age jumps to 70 years.

Further erosion in the total faculty size will continue the leverage reducing the size of the junior faculty. Even a constant faculty size will cause further deterioration in the hiring and percentage of junior faculty unless about three percent or more of the Professors leave each year. In fact, if the actual employment parameters of the past year are maintained, then a constant faculty size will result in faculty that will be only ten percent junior in 1990, as shown in Table 6.2.

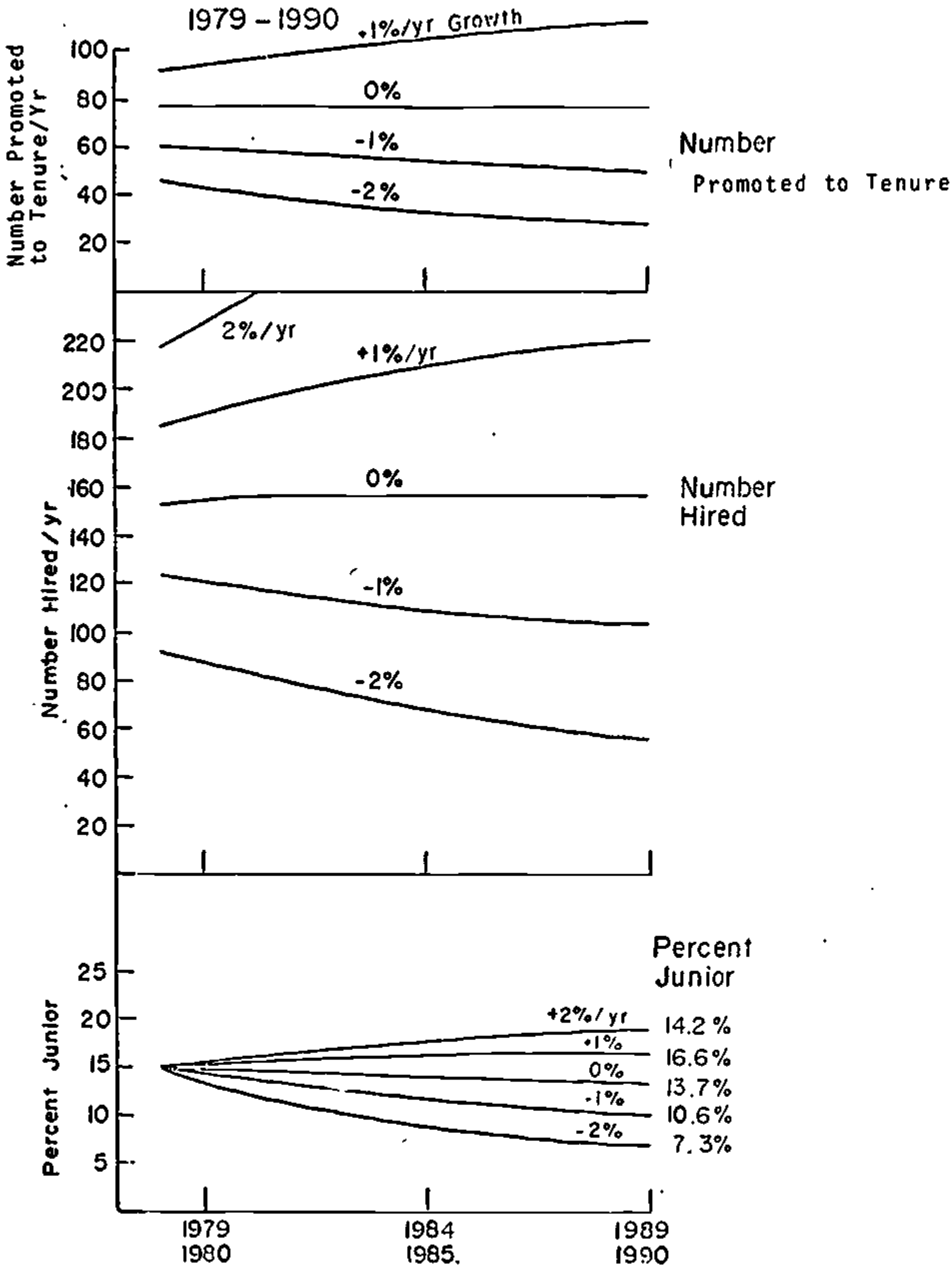
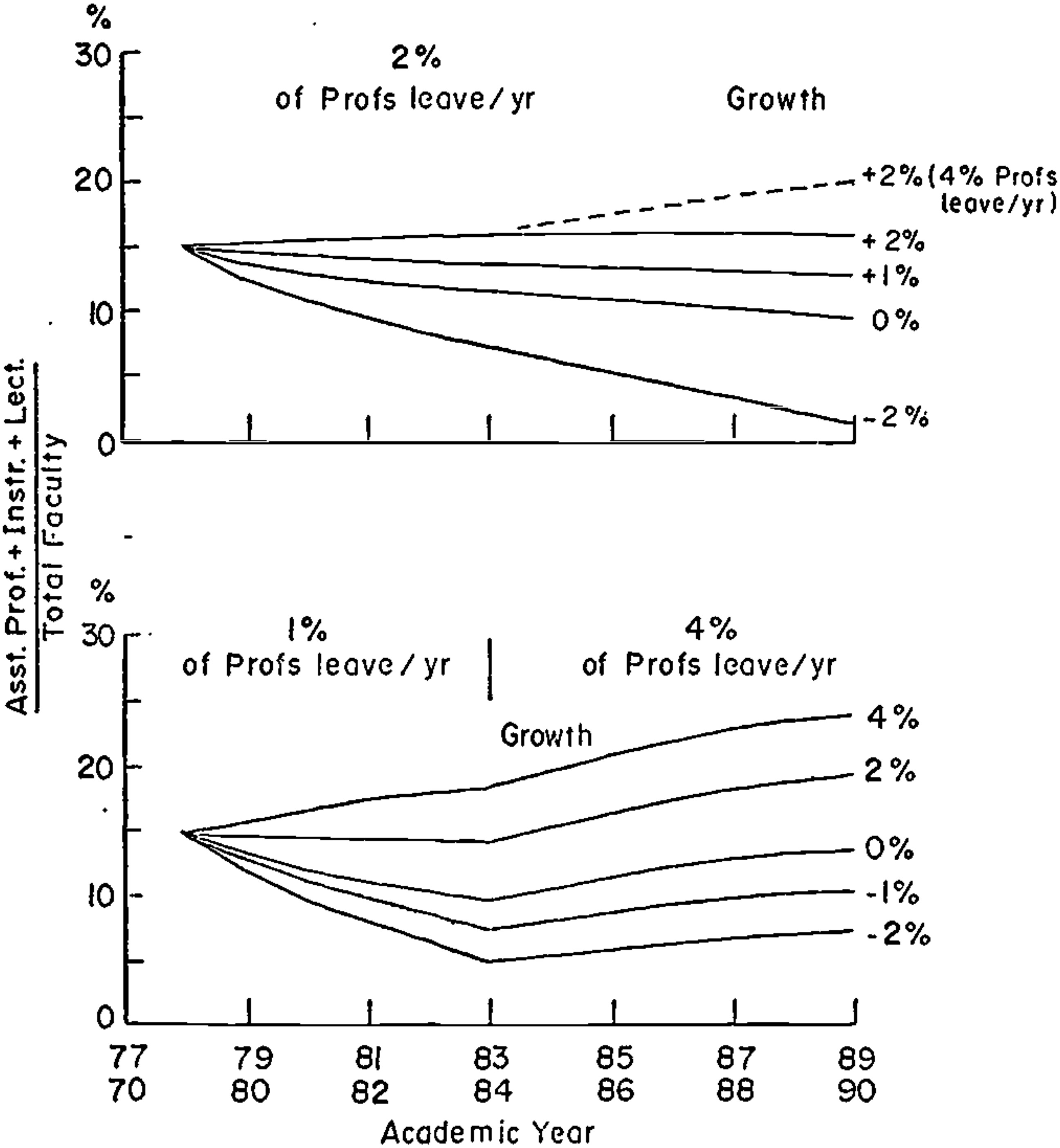


FIGURE 6.5

PROJECTION OF PROMOTION, HIRING, AND FACULTY COMPOSITION TO 1990.

Note: Assumes 2.5% senior faculty leave each year.



PROJECTIONS OF PERCENTAGE OF JUNIOR FACULTY TO 1990, WITH ALTERNATIVE ASSUMPTIONS ABOUT RATES OF EXIT OF SENIOR FACULTY

FIGURE 6.6

TABLE 6.2

EFFECT OF TURNOVER IN RANKS ON A FACULTY OF CONSTANT SIZE

Years as:											
Professor	20	25	33	50	50	→	→	→	40	33	25
Associate	7	→	→	→	10	8	6	4	13	10	8
Assistant	4	→	→	→	5	4	3	2	5	4	6
Inst./Lect.	2.5	→	→	→	3.3	3	2	1	3	3.3	3
1984-85 Junior/Total Faculty Ratio	16.8%	14.9%	13.1%	11.7%	12.4%	11.1%	9.2%	6.3%	14.1%	14.9%	14.8%
Hires/Year as Percent of Total (53% promoted to tenure)	6%	5.3%	4.4%	3.5%	3.1%	3.4%	3.7%	4.0%	3.2%	4.2%	5.1%
1989-90 Junior/Total Faculty Ratio	17.3%	15.0%	12.6%	10.0%	11.4%	9.9%	7.8%	5.2%	13.8%	15.0%	14.9%
Hires/Year as Percent of Total (53% promoted to tenure)	6.1%	5.3%	4.3%	3.3%	3.0%	3.2%	3.5%	3.6%	3.3%	4.2%	5.1%

Starting Input 1978-79		Percent New Hires by Rank	Percent Promoted to Rank
Professors	1888	16%	80%
Associates	717	11	53.5
Assistants	406	59	25
Inst./Lects.	52	14	
TOTAL	3063		
15% Junior/Total		139 New Hires in 1978-79	4.5% of Total

SOURCE: Basic data from AIP Directories of Physics and Astronomy Faculties in North America

Probability of Obtaining Tenure in a Ph.D.-Granting Physics or Astronomy Department

Comparison of these demand projections with our earlier work on supply projections (Grodzins, 1979a) permits simple predictions on the probability that a member of a Ph.D. class will become tenured in a research-oriented physics department some years after graduation. Such a calculation assumes much and ignores much, including any variation of parameters with time.

The number of tenure positions per year is obtained by the appropriate multiplication of the number hired at the junior ranks by the respective probabilities of promotion. For the calculations resulting in the number of Figure 6.7, the "best" model calculation was used; the faculty size was assumed constant after 1979. We further assumed that the average junior faculty member entered academia three years after obtaining the Ph.D. The probability of eventually being a tenured member of the 100 oldest or of any doctoral-granting physics or astronomy department is then obtained by dividing the number of tenure-track openings, determined at the time of entrance to academia, by the number entering the labor force three years prior to that entrance.

The number absorbed into the 100 older departments is shown in the bottom of Figure 6.7; the probability of attaining tenure is shown at the top. In the early 1960's, between 30 and 40 percent of all Ph.D.'s found tenured positions in doctoral-granting physics departments. The probabilities have dropped to below ten percent in the 1970's. They are expected to grow slightly to the 12-15 percent range by the mid-1980's.

The simplistic model used for the calculations of Figure 6.7 finds some support from a cohort study done three years ago. Cohort groups were followed from 1963 through 1975 with the use of the American Institute of Physics directories. A four-year time lag between the Ph.D. award and entering academia was assumed. The results are shown in Table 6.3; the underlined values are estimates. We concluded, with far fewer assumptions than used for Figure 6.7, that 34, 14, and 8 percent of the Ph.D. classes of 1964, 1967, and 1970, respectively, attained tenure in a doctoral-granting physics or astronomy department. The agreement of the model with the "data" is good

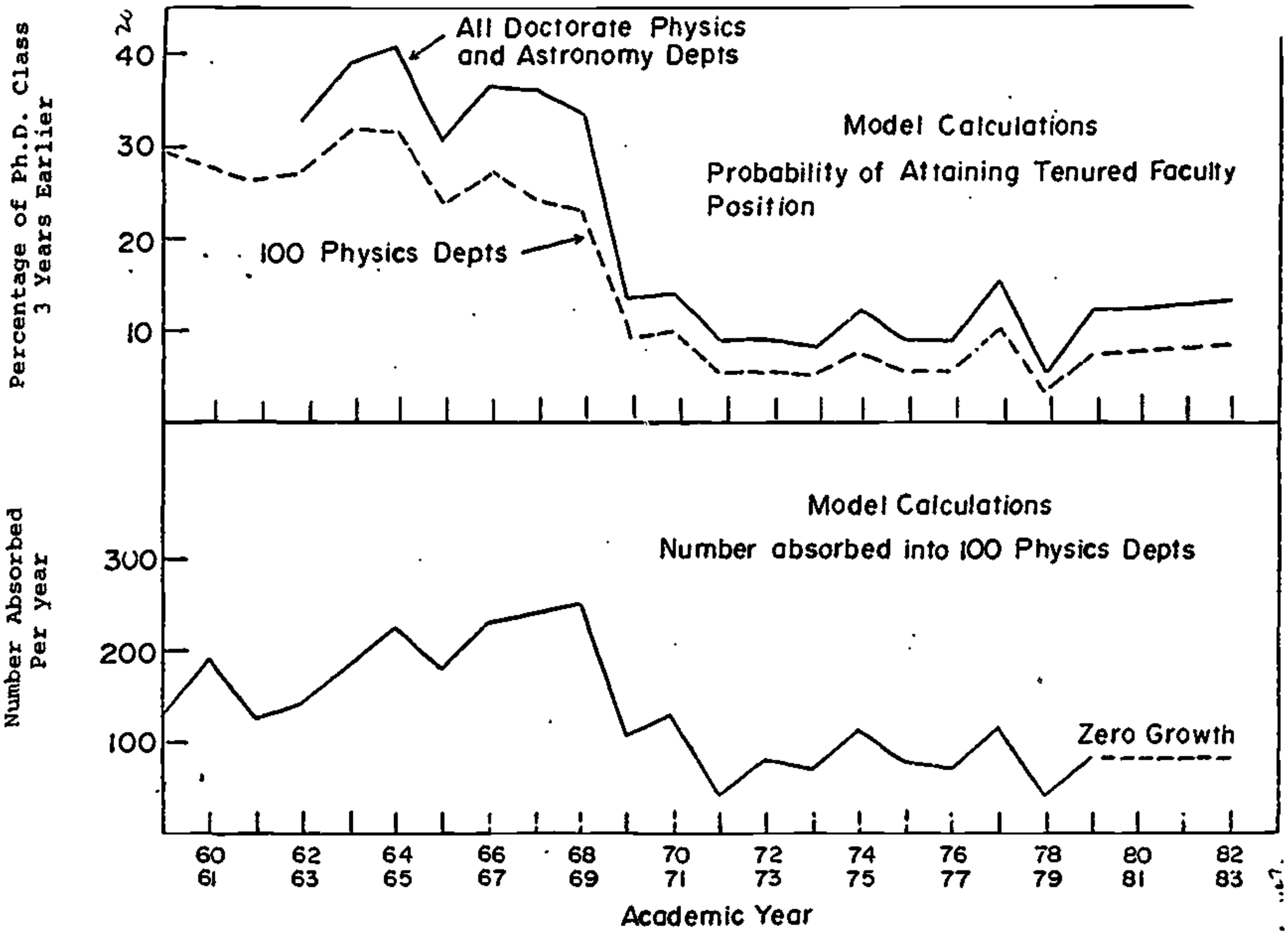


FIGURE 6.7

MODEL CALCULATIONS OF TENURE PROBABILITIES AND NUMBERS OBTAINING TENURE, 1960-83

TABLE 6.3

PERCENTAGE OF A PHYSICS/ASTRONOMY Ph.D. CLASS ATTAINING TENURE (ASSOCIATE PROFESSOR RANK)

Ph.D. Year	Number of Ph.D.'s	Number Entering Job Market	Number Entering Faculty 4 Years Later	Percent That Stick	Percentage of Ph.D.'s Entering Physics Labor Market Who Attain Tenure
1959-60	574	520 (90%)	350	70%	47%
1963-64	792	713 (90%)	350	70%	34%
1966-67	1233	1085 (85%)	260	57%	14%
1969-70	1545	1236 (80%)	200	50%	8%
1974-75	1293	989 (77%)	200	40%	8%
1978-79	1100	850 (77%)	200	50%	12%

NOTE: 1. A fixed interval of four years is assumed between Ph.D. date and first entrance into faculty ranks.

2. Underlined values are estimates (see text).

for the 1964 and 1970 classes, but the model apparently missed the sharp drop in the "sticking" probability by one year.

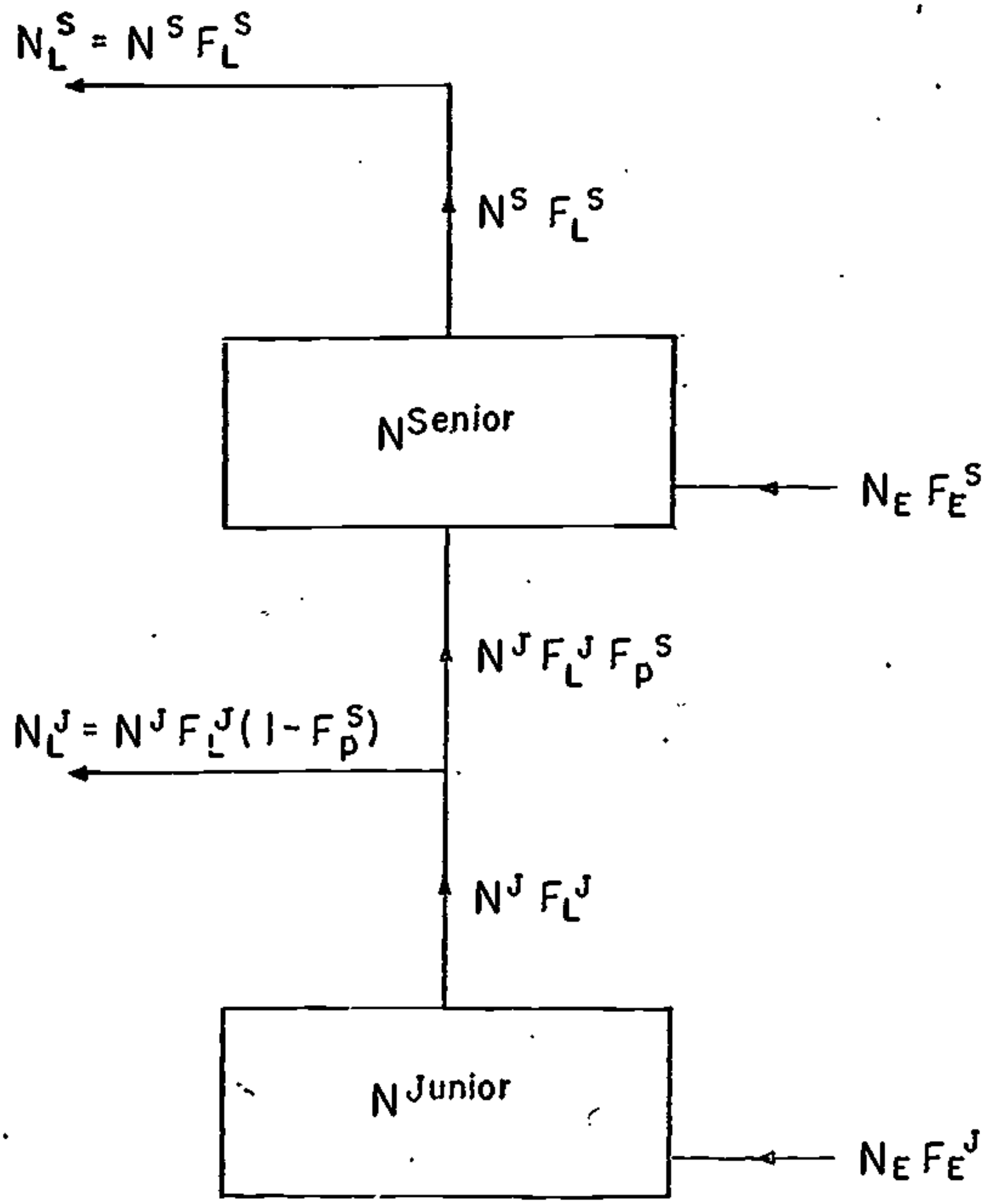
Finally, we emphasize that these projections are for all of physics in doctoral-granting physics and astronomy departments. The projections should not be applied to the non-doctoral departments, which, we believe, will feel severely the effects of the declining 18-21-year-old population. Nor should the projections be applied to the sub-fields of physics. For example, it is likely that the probability that a nuclear physicist, who obtains a Ph.D. in 1981, will attain tenure in a doctoral-granting department may be close to 30 percent, while the analogous odds for an astrophysicist may be less than ten percent.

II. Projected Demand for Science and Engineering Faculty, 1974-1990

The projections for physics just described are based on census data available for physics faculties from 1959 through 1979. Such a detailed approach is impractical in fields other than physics since the data are not available. For other fields we have secure information only for recent years and then only for growth rates and for changes in faculty composition, in particular the changes in the percentages of the faculties that received doctorates within seven years of the survey. A more simplified two-tiered model is appropriate.

Figure 6.8 shows a schematic drawing of such a model. The faculty is divided into junior and senior (or recent and long-ago) members. The fraction of the senior faculty that leave per year, F_L^S, is generally in the range of two to four percent. The fraction who leave junior (recent) ranks of a given institution each year, F_L^J, is between 20 and 35 percent; i.e., the length of time spent in the junior (recent) ranks is between three and five years. Of those hired each year, a certain fraction, F_E^J, are into the junior ranks, the remainder go into senior ranks.

To use the model, one starts with initial values for the number of senior and junior faculty in an initial year. Each year, a fraction, F_L^J, of the junior and, F_L^S, of the senior faculty leave their respective ranks. Of the former, a fraction, F_P^S, get promoted. The number that are hired is the growth plus replacement. The values of the parameters are assumed to be fixed in time.



$$F_E^S + F_E^J = 1$$

$$N_E = N_L^S + N_L^J + G(N^S + N^J)$$

A TWO-TIERED MODEL OF FACULTY FLOWS

FIGURE 6.8

Such a two-tiered model fits historical data on physics faculty rather well. In Figure 6.9, the number of junior and senior faculties is shown in 100 Ph.D. physics departments from 1959-60 to 1977-78 (solid lines) together with the "best fit" based on one set of parameters.

<u>Equation 1</u>

$$F_L^S = 0.035 \qquad F_L^J = 0.33$$

$$F_P^S = 0.350 \qquad F_E^S = 0.15$$

The only variable is the total size of the physics faculties in the 100 institutions each year. As in Part 1 above, only minimum effort was made to find a good fit and that was judged by eye. The parameters in Equation 1 are not optimum for extrapolation since they are average values over a constantly shrinking Instructor rank, once so important. In recent years, that rank has all but disappeared and the values of F_L^J and F_P^S are now close to 0.25 and 0.45 respectively.

The good fit over a 20-year period shown in Figure 6.9 with not unreasonable parameters encourages application of the model to the fragmentary data of Atelsek and Gomberg (1979). Figure 6.10 shows the result of fitting the data for all the science and engineering fields surveyed by Atelsek and Gomberg to the two-tiered model. Curves 1, 2, and 3 assume the total faculty growth rate of the recent past. There is little to choose among the different parameter sets, although set 3 does best for data from 1973 on. When the fraction of recent doctorates is extrapolated to 1990, we find that even if faculty growth rates of one percent per year continue, the fraction will fall to about 20 percent. But growth rates in the 1980's are more likely to be negative than positive. Extrapolations 4 and 5 with zero and minus one percent per year growth rates are more realistic. However, as the academic market turns down, there is likely to be an increased exodus from senior ranks. (The tenure system prevents faculty being pushed out; those pulled away will be from among the best.) Curves 4 and 5 assume that F_L^S fractions will increase by one percentage point. The overlap of curves 3 and 4 illustrates the obvious fact that a decrease in growth rate is equivalent to an increase in exodus rate. If the faculty shrinks by one percent per year (somewhat less than the decline in the 18-22-year population) the fraction

FIGURE 6.9

SENIOR-JUNIOR FACULTY COMPOSITION IN
100 PH.D.-GRANTING PHYSICS DEPARTMENTS

1960-1978
DATA COMPARED TO MODEL CALCULATIONS

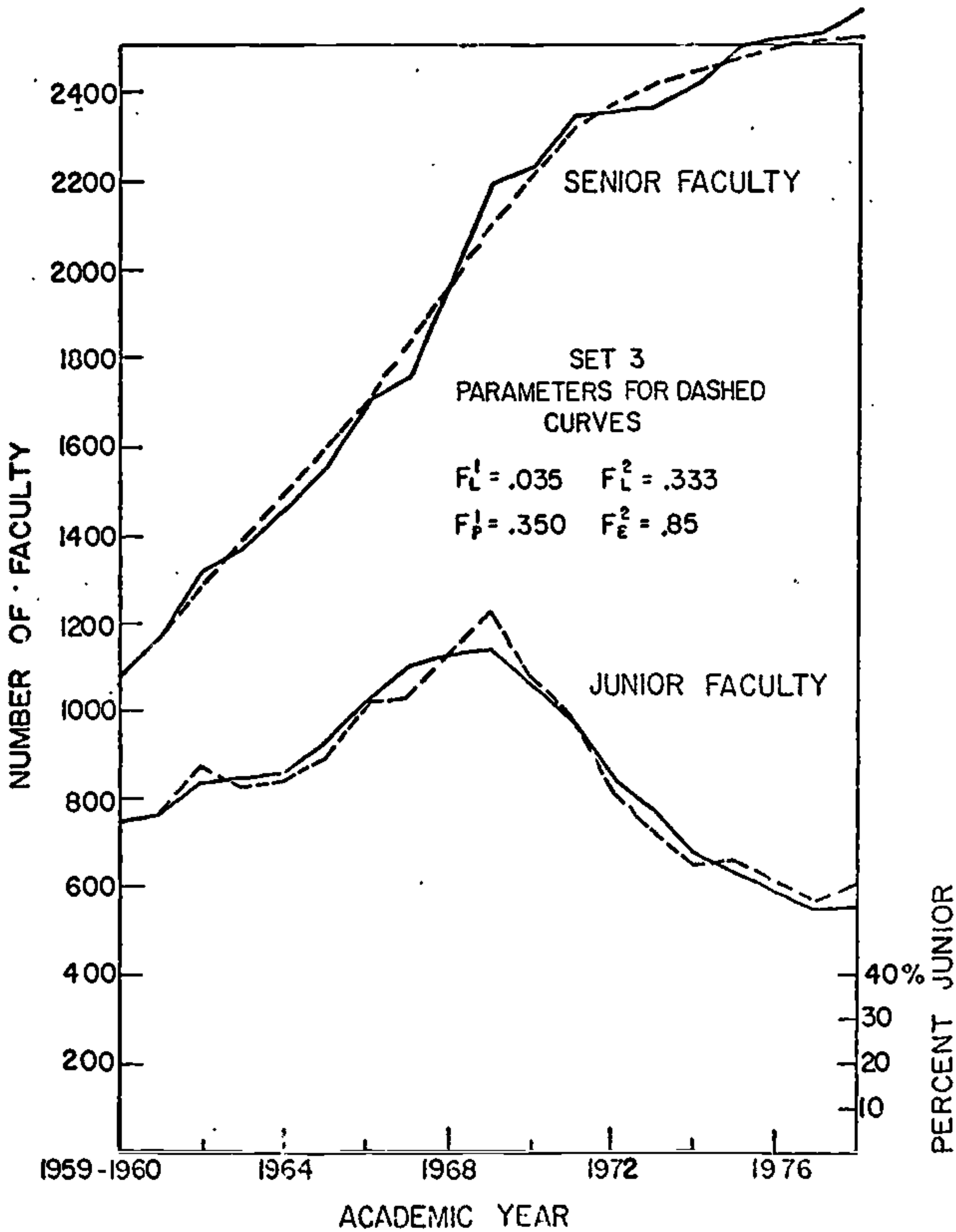
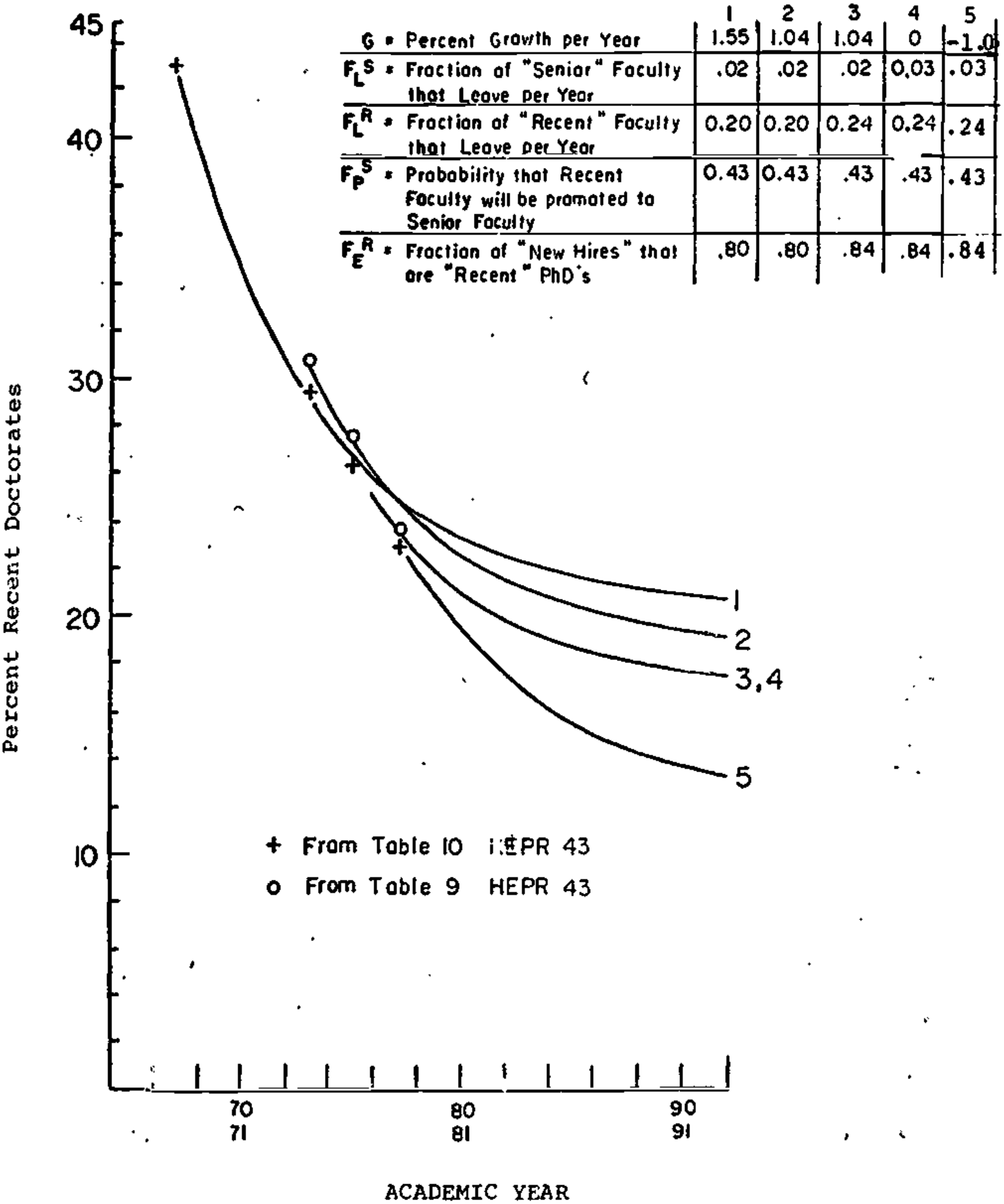


FIGURE 6.10

PROJECTED TRENDS IN SCIENCE-ENGINEERING FACULTIES
BASED ON DATA FROM ATELSEK AND GOMBERG, HEPR 43



	1	2	3	4	5
G = Percent Growth per Year	1.55	1.04	1.04	0	-1.0
F_L^S = Fraction of "Senior" Faculty that Leave per Year	.02	.02	.02	0.03	.03
F_L^R = Fraction of "Recent" Faculty that Leave per Year	0.20	0.20	0.24	0.24	.24
F_P^S = Probability that Recent Faculty will be promoted to Senior Faculty	0.43	0.43	.43	.43	.43
F_E^R = Fraction of "New Hires" that are "Recent" PhD's	.80	.80	.84	.84	.84

of recent doctorates on faculties (curve 5) will contract significantly, even with increased exodus of senior faculty; the percent recent doctorates will fall to 13 percent.

The Atelsek-Gomberg data are from only a portion of the total science and engineering academic community, although within the 19 fields covered a significant fraction of the leading research departments answered the survey. A broader data base is available from the National Research Council's (NRC) Surveys of Doctoral Scientists and Engineers which were carried out in 1973, 1975, and 1977. Figure 6.11 shows the trends in the percent recent doctorates on the faculties in those three years. While the definitions used to cull the results from the NRC data were presumably the same as for the Higher Education Panel Report (HEPR) study, the NRC values are considerably higher, though with similar trends. The discrepancy is almost certainly due to the vagueness of the phrase "within seven years" of the doctorate. We expect that the NRC data contain at least one more year of doctorates than does the HEPR data. When the model is fitted to the data, assuming again a 1.1 percent per year growth in total faculty, a good fit is obtained with parameters not very different from those of curves 1 and 2 of Figure 6.10. The suitability of fit is primarily a function of the rates of changes of the factors and not of the absolute values. Two extrapolations are made; one for no growth, the other for a 1.1 percent growth. The former results in a 20 percent recent doctorate component in 1990.

The extrapolations of Figures 6.10 and 6.11 for the aggregated faculties are useful overviews but are not particularly helpful for decision-making, since individual fields differ widely. Figure 6.12 shows the data from Atelsek and Gomberg (1979) for five fields: chemistry, electrical engineering, mathematics, physics, and psychology. The initial values of the fraction of new doctorates differ by more than a factor of two. So, too, do the slopes of the curves. The initially high-valued fields have been falling precipitously; fields which have already taken their lumps are changing slowly.

If zero growth rates are the rule in the 1980's, then we can expect that by 1990, the percentages of recent doctorates will range from a high of 20 percent (psychology) to a low of 10 percent (physics). The latter

FIGURE 6.11

PROJECTED TRENDS IN SCIENCE PLUS ENGINEERING FACULTIES
BASED ON NRC SURVEYS, 1973, 1975, and 1977

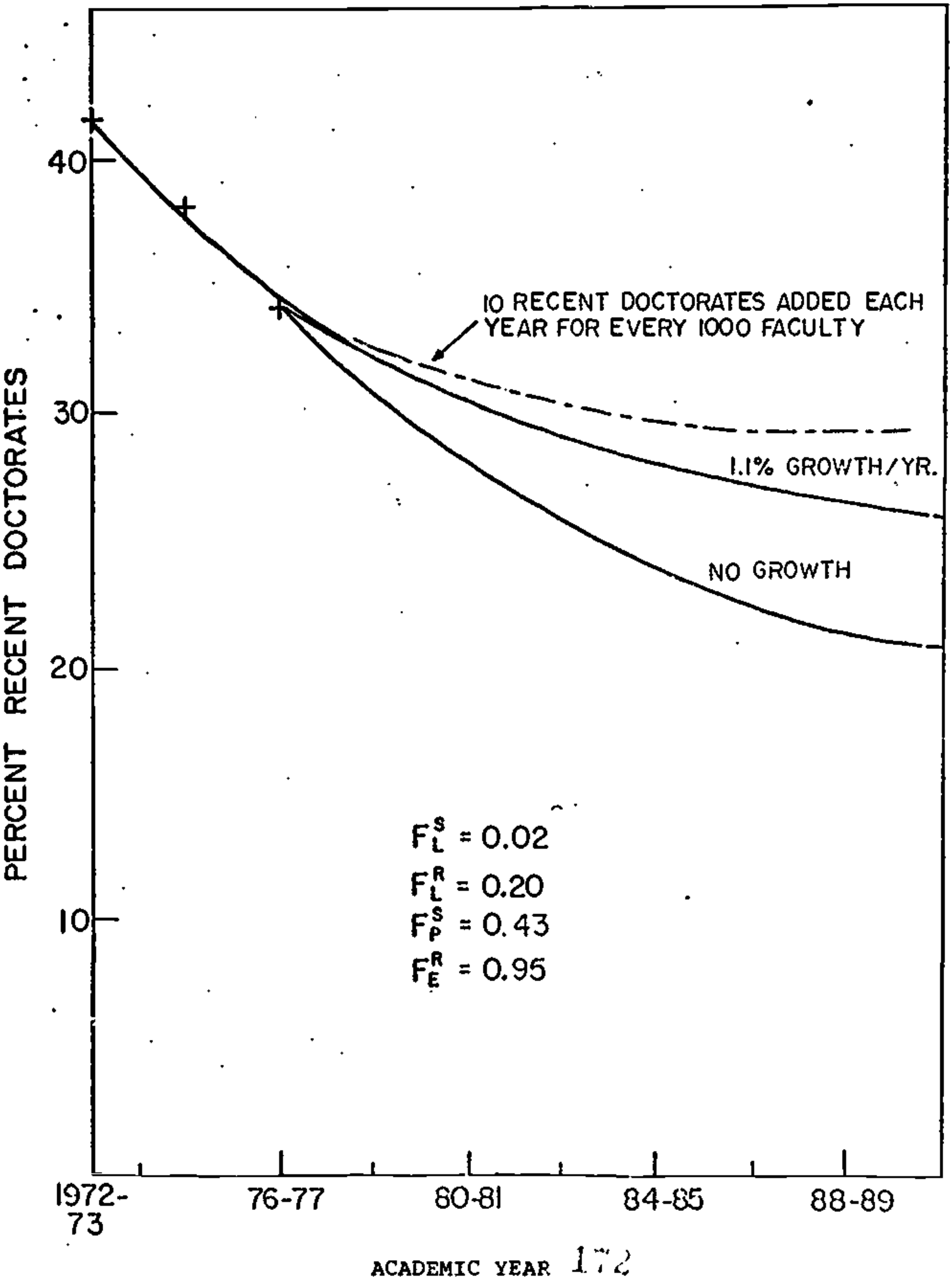
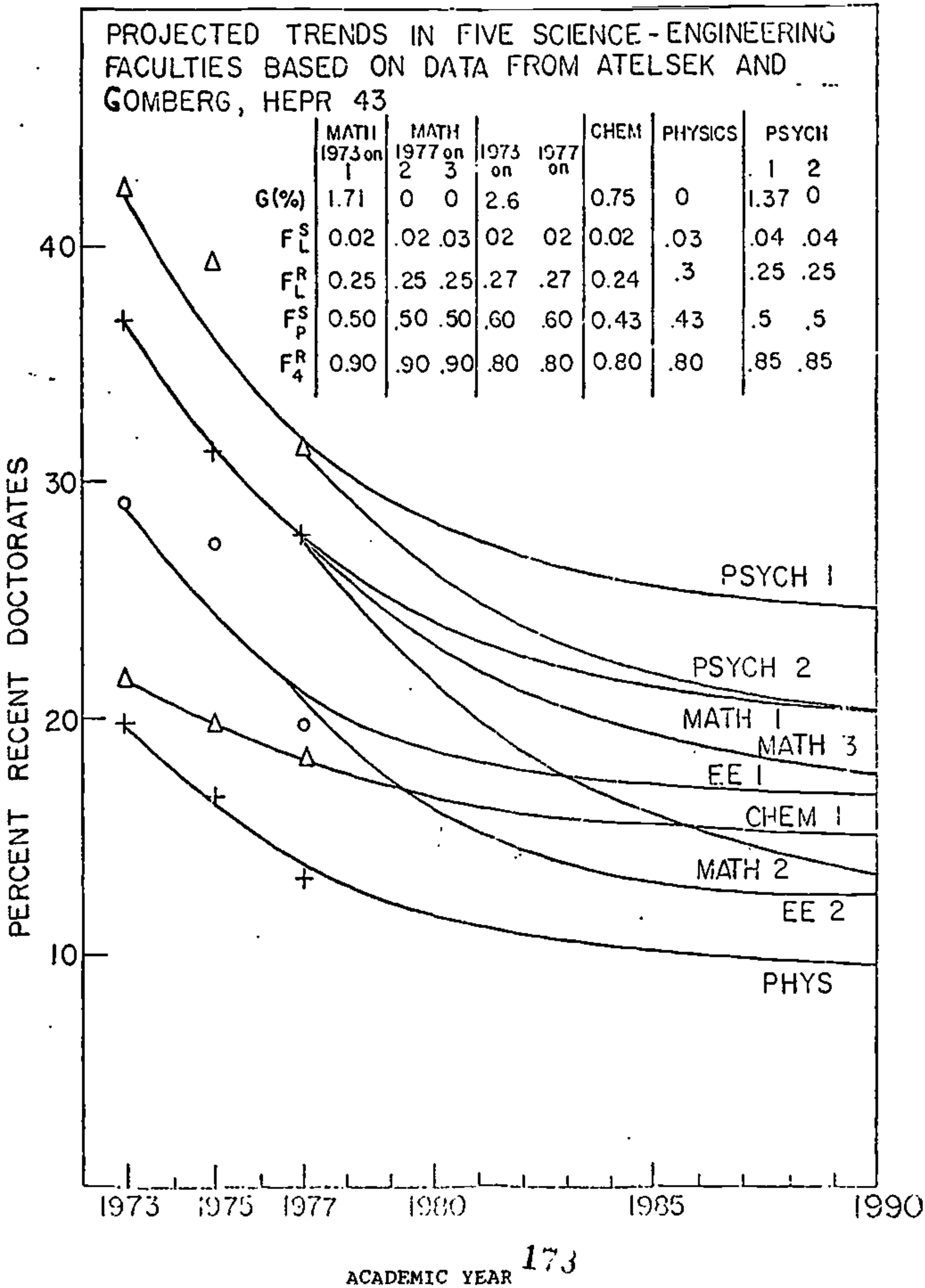


FIGURE 6.12



	MATH 1973 on 1	MATH 1977 on 2	3	1973 on	1977 on	CHEM	PHYSICS	PSYCH 1	2
G(%)	1.71	0	0	2.6		0.75	0	1.37	0
F_L^S	0.02	.02	.03	02	02	0.02	.03	.04	.04
F_L^R	0.25	.25	.25	.27	.27	0.24	.3	.25	.25
F_P^S	0.50	.50	.50	.60	.60	0.43	.43	.5	.5
F_4^R	0.90	.90	.90	.80	.80	0.80	.80	.85	.85

value is similar to the predictions in Part I where we showed that for physics the use of junior faculty is roughly equivalent to the "within seven years" faculty.

We have not considered negative faculty growth rates in Figure 12, even though we believe that many fields will suffer such declines, since we anticipate that increased exodus from the senior ranks will add openings to compensate for the decreased size.

III. The Effect of an Add-On Scholars Program

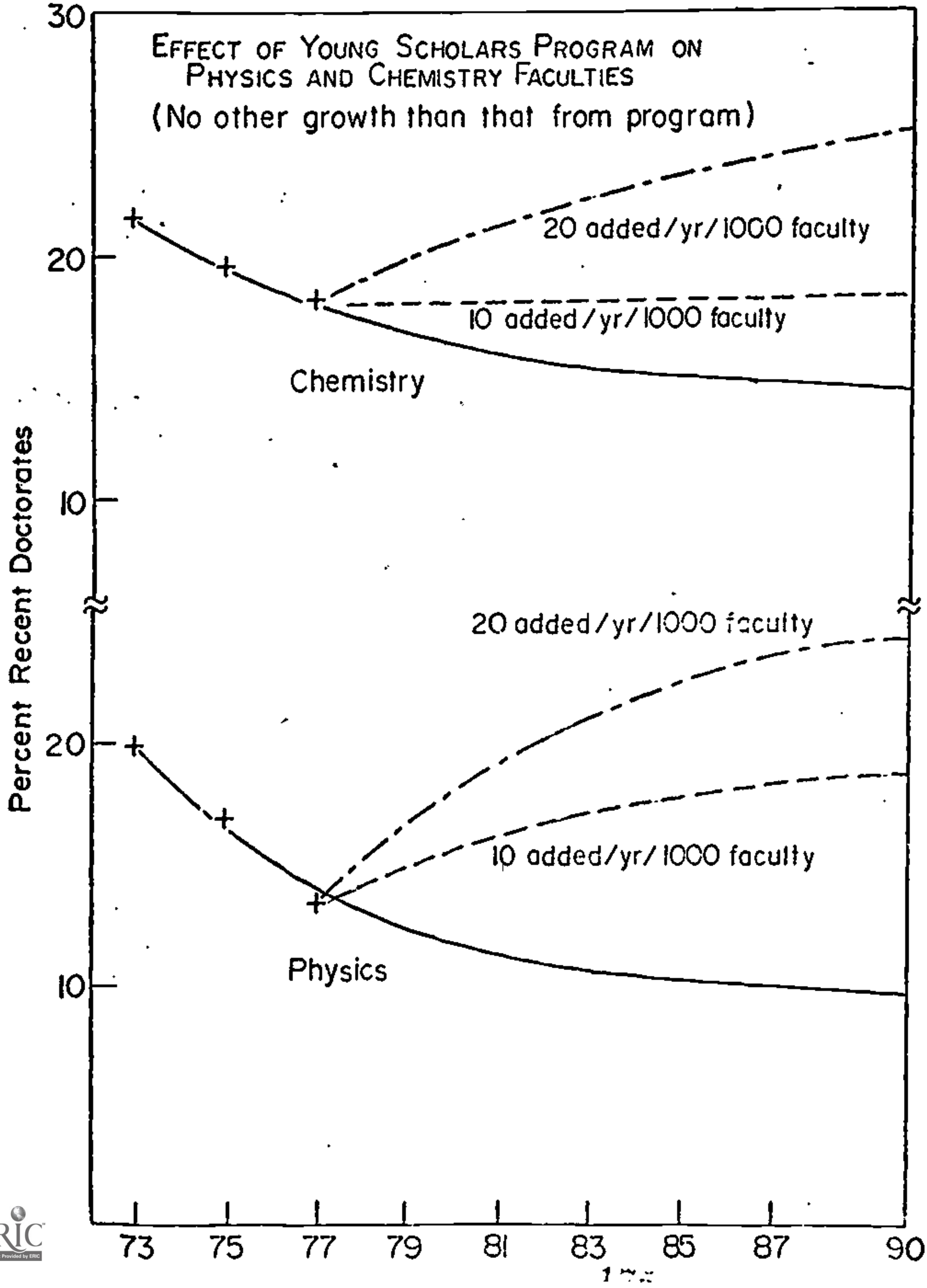
The research community is complex, with many interconnected forces working to maintain the research strength which is the primary function of the community; like a living organism, research academe has evolved to withstand buffeting. The loss in research vitality and in total research productivity as a result of a shrinking young faculty will become transparently clear only when the situation becomes much worse than now. If we do not heed the clear warning signs of enfeeblement, it will take a decade to heal the damage. The most obvious cure is an injection of young scholars. We will not discuss here any specific proposal, such as that proposed by the NRC's Committee on Continuity in Academic Research Performance (National Research Council, 1979), but will assess the consequences of a general add-on scholars program.

The criteria for an add-on program are that recent doctorates are hired beyond the numbers that would be hired without the program and that the promotion percentages from Assistant to Associate Professor do not decline. Such criteria are easily incorporated into the model of Figure 6.8.

In Figure 6.11, we show the effect of a program which would add, each year, ten "recent" doctorates for every 1,000 faculty in science and engineering. We have assumed no growth apart from the new program. Such a program will slow but will not stem the downturn.

In Figure 6.13, we show the effects in physics and chemistry of a yearly program of adding 10 and 20 scholars for every 1,000 faculty. The asymptotic results of these programs are almost independent of the starting conditions. For both physics and chemistry, a program of ten scholars per 1,000 faculty will result in 18 percent having "recent" doctorates; a program of 20 scholars per 1,000 faculty will result in a 24 percent fraction. In

FIGURE 6.13


EFFECT OF YOUNG SCHOLARS PROGRAM ON PHYSICS AND CHEMISTRY FACULTIES
(No other growth than that from program)
20 added/yr/1000 faculty
10 added/yr/1000 faculty
Chemistry
20 added/yr/1000 faculty
10 added/yr/1000 faculty
Physics
Percent Recent Doctorates
30
20
10
20
10
73
75
77
79
81
83
85
87
90

physics these programs are about equivalent to adding 30 and 60 new Assistant Professors respectively into the 100 leading research-oriented faculties and the results are consistent with the projections in Part 1 using the four-tiered model.

The smaller programs will stop the erosion but the final result will be below "steady state." The larger program will bring the faculties almost to the "steady-state" conditions. We did not incorporate a phase-out to the programs in Figures 6.11 and 6.13, but as we have stated before, and as is specifically a part of the recommendations of the Committee on Continuity in Academic Research Performance, the add-on program should phase out as retirements increase (F_L^S) to equilibrium values of three to four percent.

Comment I.

Physics faculties are in greater difficulty than is indicated by the NRC data quoted in the Report of the Committee on Continuity in Academic Research Performance (National Research Council, 1979, p. 105). The NRC data indicate a growth of 1.7 percent between 1975 and 1977, but both the Atelsek and Gomberg data and the census of all the faculties of physics show no growth. (The census data show a small but steady decline from 1971 through 1979.) The discrepancy between the actual values and the NRC survey data, results from the fact that the latter do not distinguish departments in which physicists are housed; the respondent to the survey gives only the name of the employer and his employment specialty. In recent years, the downturn in job opportunities for physicists resulted in large numbers being available and many were hired into faculty positions in other departments. Between 1973 and 1977, more than 300 Ph.D. physicists were so hired, mainly into engineering and earth science faculties. Physics faculties did not get the benefit of these young scientists.

Comment II.

The extrapolations of Figures 6.10, 6.11, and 6.12 predict that the percentage of recent doctorates will fall below the "steady-state" value in all fields by 1990. There is considerable ambiguity to determining the steady-state value for "recent" doctorates. If, for example, all seven years are spent on the faculty, then the steady-state percentage is 35 percent; if only five of the seven years are in faculty positions, then the percentage of the faculty that hold recent doctorates will drop to 28 percent. (We have assumed an average age at the doctorate of 29, a mean average at retirement of 65 and a probability of promotion of 45 percent.) Much less ambiguity is encountered if one used the percentage junior faculty (Assistant Professor and below) as the measure of "young." For physics that value is 15 percent and is expected to fall to 10 percent. The average length of time spent in the Assistant Professor rank is four years so that the continuity equations at steady-state give an equilibrium fraction of 22 percent, assuming entrance and retirement ages of 30 and 65 and a 45 percent promotion rate. Physics faculties are now at two-thirds the equilibrium value and will fall below the 50 percent mark by the mid-1980's.

The use of equilibrium values provides useful bench marks but we had better understand just how different will be the world of research-oriented faculties when we reach that unhappy state. At equilibrium, the mean age of the faculty will be 46 to 48 years (depending on retirement age); 45 percent of the faculty will be over 50 years old, assuming a retirement age of 70. We older folk are no doubt as intelligent and as creative as we were when young, but will we do as much research, start as many new projects, have as much incentive, time, energy?

Comment III.

The more senior the faculty the more it will cost. In research-oriented departments a full Professor may cost a university three times as much as an Assistant Professor who may get a part of his term salary from a research grant. And, if the past is a guide to the future, the senior faculty will do less research than would a younger faculty.

The mean times spent in research and in research plus development are given in Table 6.4 as a function of faculty rank for each broad field. Assistant Professors consistently spend a larger fraction of their time on research and development than Professors - hardly a surprise. If these percentages prevail in the future, then the full-time equivalent research population will decline as the faculties become more senior. Specifically, in a faculty of constant size, a decline in the percentage of junior faculty from 30 to 20

TABLE 6.4

MEAN PERCENTAGE OF TIME SPENT ON RESEARCH BY FACULTY RANK*

Mean Percentage of Time the Faculties in Ph.D.-Granting Institutions Were Involved in Basic Research in 1977

	Total Faculty	Professor	Associate Professor	Assistant Professor
All Fields	20.4%	18.2%	19.7%	25.0%
Mathematics	24.2	21.6	24.1	27.7
Physics	34.1	32.9	32.7	38.6
Chemistry	32.7	28.8	33.5	40.2
Earth Sciences	24.9	23.5	21.9	31.0
Engineering	8.7	8.0	7.7	12.1
Agricultural Sciences	9.1	8.2	10.7	8.8
Biological Sciences	30.1	26.1	29.0	36.8
Psychology	14.8	14.0	14.2	17.3
Social Sciences	14.9	13.3	14.4	17.8

Mean Percentage of Time the Faculties in Ph.D.-Granting Institutions Were Involved in Research and Development in 1977

	Total Faculty	Professor	Associate Professor	Assistant Professor
All Fields	30.9%	28.2%	31.1%	35.5%
Mathematics	29.3	27.8	28.5	32.0
Physics	38.5	36.7	37.0	44.5
Chemistry	35.7	31.2	36.3	44.8
Earth Sciences	32.9	29.8	32.4	39.5
Engineering	27.0	24.3	29.4	35.4
Agricultural Sciences	39.2	37.4	40.2	42.8
Biological Sciences	38.0	33.3	37.5	44.7
Psychology	23.8	21.7	23.8	26.8
Social Sciences	23.3	21.7	23.8	25.3

From 1977 NRC Survey of Doctoral Scientists and Engineers percent would result in a loss of full-time research and development equivalents of 0.4 percent, 0.8 percent, 0.9 percent, and 1.0 percent for mathematics, physics, chemistry, and biosciences, respectively.

---

*I would like to thank Porter Coggeshall for helpful discussions and the Commission on Human Resources for supplying the data for Figure 11 and Table 4.

REFERENCES

Atelsek, F. J. and I. L. Gomberg. Young Doctorate Faculty in Science and Engineering: Trends in Composition and Research Activity. Higher Education Panel Report No. 43, Washington, D.C.: American Council on Education, 1979.

Grodzins, L. Supply and Demand for Ph.D. Physicists, Section II. A Report of the American Physical Society Manpower Panel, M. D. Fiske, Chairman, 1979a, pp. 339-360.

_______. Supply and Demand for Ph.D. Physicists, Section III. A Report of the American Physical Society Manpower Panel, M. D. Fiske, Chairman, 1979b, pp. 361-381.

National Research Council. Commission on Human Resources. Doctoral Scientists and Engineers in the United States, 1973 Profile. Washington, D.C.: National Academy of Sciences, 1974.

_______. Commission on Human Resources. Doctoral Scientists and Engineers in the United States, 1975 Profile. Washington, D.C.: National Academy of Sciences, 1976.

_______. Commission on Human Resources. Science, Engineering, and Humanities Doctorates in the United States, 1977 Profile. Washington, D.C.: National Academy of Sciences, 1978.

_______. Commission on Human Resources. Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. Washington, D.C.: National Academy of Sciences, 1979.

CHAPTER VII

AGING FIELDS: PROJECTIONS OF NEW HIRES AND YOUNG FACULTY RATIOS FOR BROAD SCIENCE AND ENGINEERING FIELDS: 1976 TO 2000*

Charlotte V. Kuh
Harvard Graduate School of Education

I. Introduction

It is the purpose of this paper to report the results of the application of the model described in "Reconcilable Differences?," which appears earlier in this volume, to particular broad fields in science and engineering. The fields are physical science (defined here as including both physical and environmental science), mathematical science, social science (including psychology), and engineering. It is found that the projections of demand vary significantly from field to field. Nevertheless, all fields except physical science are expected to experience marked declines in new hiring from a peak in 1980 to a trough in the mid-1980's, followed by a pick-up in the late eighties and then by another, far more precipitous, decline. New hiring in physical science does not decline until 1990.

The effect on the ratio of young faculty to total faculty of these patterns of new hiring is discussed. The manner in which field-specific demography affects new hiring is also described.

II. Why Broad Fields, and Other Caveats

It can easily be argued that the proper units of disaggregation relevant to the "health" of the process that produces knowledge in a particular discipline is the discipline itself, molecular biology or econometrics, for example. And even given this fine a disaggregation, fundamental changes in knowledge are only produced by a few scientists at a few universities (Klitgard, 1979). Why, then, does this study examine such broadly aggregated fields?

The defense of the use of broad fields is, in part, one of statistical necessity--our statistical techniques require that there not be too many

*The research for this project was completed while the author was Assistant Professor, Harvard Graduate School of Education, and was conducted with research support from the National Science Foundation. I wish to thank David Bussard and Bernard Morris for research assistance.

zeroes in the matrices from which we estimate transition probabilities. In addition to this practical argument, however, there is a certain amount of theoretical justification. The few scientists at the few universities are the outcome of a process that involves a great many more people than just themselves. They carry out their work with the help, in part, of students who feel that a career exists for them in science and hence have undertaken graduate study. The "best" are found through a lengthy process that involves career decisions by students, admission decisions by colleges and graduate schools, funding decisions by those organizations that support research, and hiring decisions by academic and non-academic employers. We do not really know what happens to the rest of this chain of decisions when changes in the external environment, student demand, for example, affect hiring decisions. Ignorance, however, should not be an excuse for complacency.

The results presented below should not be used to make statements such as "Academic hiring in economics is going to decline by 62 percent in the 1980's." Such a statement ignores the fact that these projections are for broad fields, and hence average the experience and demography of economics, sociology, political science, and psychology. Furthermore, these forecasts are subject to all sorts of uncertainty about parameters. For example, a high rate of inflation in the 1980's may mean that many faculty members decide not to retire until age 70 or later. This would mean that, given faculty/student ratios, there could be even less new hiring. On the other hand, institutions, aiming to reduce costs, might become much more reliant on part-time faculty. This would change faculty/student ratios and result in the hiring of more people although their incomes might be seriously affected.

The purpose of presenting these projections, then, is to explore the implications of faculty demography and projected enrollments for the evolution of the age and tenure structure for broad fields and, consequently, for new hiring and young faculty ratios. Parameters could very well change in the 1980's in ways we have not anticipated.[1/] Demographic evolution could

---

[1/] A certain amount of "economic" adjustment is built into the model through the assumption that attrition rates will double in the 1980's and then return to earlier levels, that promotion rates will decline in the '80's, and that there will be a moderate adjustment to the change in mandatory retirement legislation.

conceivably have no effect on the production of knowledge. Older might well be wiser. We leave the answers to these questions to other researchers.

III. Initial Conditions: The Demographic Shape of the Fields

A. Data

Faculty data from two sources are used in these projections. The total size of a field in 1975 is the number of teaching faculty in four-year colleges and universities as found in the National Science Foundation *Survey of Manpower Resources for Scientific Activities at Universities and Colleges* (1975). This number includes both doctoral and non-doctoral faculty. We do not, however, have detailed demographic data about this population. For these data we rely on special tabulations for doctoral faculty provided for us from the Survey of Doctoral Scientists and Engineers of the Commission on Human Resources of the National Academy of Sciences (National Research Council, 1976). We have assumed that the demographic parameters derived for doctoral faculty are applicable to all teaching faculty.

Our projections of student enrollment by field are derived by applying the projections of earned degrees by field of the National Center for Education Statistics for the years up to 1986-87 (NCES, 1978) to our aggregate student enrollment series[2/] by assuming that a field's share of enrollments varies as its share of earned degrees. Thereafter we assume that the shares of the individual fields remain at their 1986-87 values.

B. The Fields in 1975

A summary of the initial field-specified demography is presented in Table 7.1. A more detailed breakdown for each field is presented in the Appendix.

There are clear differences among fields. Faculty in mathematics are significantly younger than faculty in other fields in both the tenured and non-tenured ranks. A little more than one-quarter of physical scientists are "young" in terms of academic age, as contrasted with 40 percent or more in both the mathematical and social sciences. Mathematical sciences, however, have a relatively high tenure ratio, while the tenure ratio for the social sciences is the lowest for any field.

[2/] For the derivation of the aggregate student enrollment series, see L. Fernandez, (1978).

Initial tenure rates and attrition rates also differ from field to field. Table 7.2 presents the tenure and attrition rates in 1976 for non-tenured faculty members of academic age three and seven.[3/] In examining Table 7.2, it is important to remember that these rates are conditional on an individual's still being a non-tenured faculty member at the academic age in question. Thus, the higher the attrition rate at early ages, the fewer faculty there are available at later ages who can become tenured. We might, therefore, expect to see a direct relationship between early attrition rates and later tenure rates. What we observe, in fact, is that physical science has low tenure rates <u>and</u> relatively high early attrition rates, while mathematics and social science have low-to-average early attrition rates and high tenure rates at age seven. Since these rates were observed during a period of growing enrollments, one might guess that these latter fields might be most seriously affected during the 1980's when enrollment growth becomes negative.

It is the interaction of these rates (which vary from field to field) plus age-specific death and retirement rates (which are assumed the same for all fields) plus the initial joint distribution of biological age, academic age, and tenure, that compose our initial conditions. Projected enrollment demand and the assumption of a given faculty/student ratio then determine the course of this population over time as faculty are hired to maintain the faculty/student ratio. The effect of these initial conditions and the resulting change in the demographic description of the population over time are presented in the following section.

IV. Results

A. New Hiring

The demand for new hires is generated, in part, by the change in faculty demand. This faculty demand relative to its 1975 level is presented in Figure 7.1 for the five separate fields. Engineering, which in the years prior to 1975 had suffered a decline, shows the greatest growth in demand in 1980. Physical and social sciences show the least growth in relative

[3/] Tables with all input parameters for all years of the model are available on request from the author.

TABLE 7.1

SUMMARY OF AGE AND TENURE CHARACTERISTICS
OF DOCTORAL FACULTY BY FIELD, 1975

Characteristic	FIELD Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
Median Biological age:					
Tenured faculty	42.3	45.6	45.5	47.6	46.4
Non-tenured faculty	34.0	35.9	36.8	36.4	36.0
Percent of academic age less than eight	40%	25.4%	27%	32.8%	44.1%
Percent Tenured	67.5%	69.6%	72.5%	66.5%	64.2%

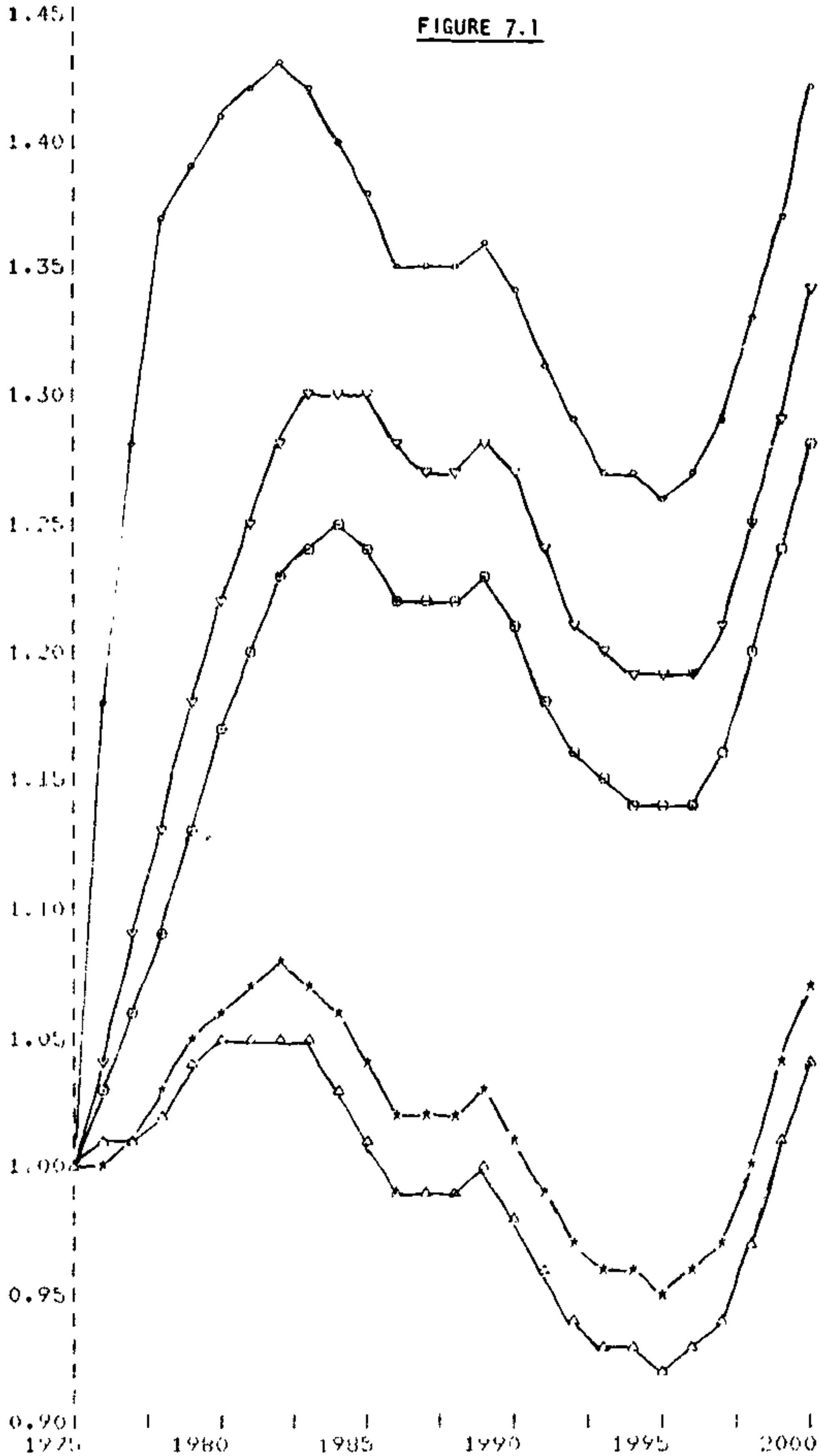
TABLE 7.2

EXAMPLES OF AGE-SPECIFIC TENURE AND ATTRITION
RATES FOR DOCTORAL FACULTY BY FIELD, 1976

	FIELD Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
Tenure rate at:					
Academic age three	.038	.024	.045	.041	.072
Academic age seven	.408	.178	.173	.214	.308
Non-tenured attrition* rate at:					
Academic age three	.039	.102	.035	.032	.023
Academic age seven	.052	.049	.078	.003	.010

*from causes other than death or retirement

FIGURE 7.1



DEMAND FOR STOCKS BY FIELD RELATIVE TO 1975 DEMAND

O MATHEMATICAL SCIENCES ∇ LIFE SCIENCES

★ PHYSICAL SCIENCES △ SOCIAL SCIENCES

demand. Between 1980 and 1985, demand for faculty in all fields declines and after a plateau in the late 1980's, demand declines at least to 1995 for all fields. It should be noted, however, that even in 1995 the size of the faculty in mathematical, life, and engineering sciences is above its 1975 level by from 10 to 30 percent. This is, however, a decline from peaks that were almost 25 to 45 percent higher than 1975 levels. For the social and physical sciences, however, demand is lower than its 1975 level by 5 to 10 percent. The levels of demand and relative demands are shown in Tables 7.3 and 7.4, respectively.

Although the shapes of demand for the several fields as shown in Figure 7.1 are similar, new hiring, whcih depends on the change in demand and the change in the existing faculty stock, is quite different across fields, as shown in Figure 7.2 and Table 7.5. Peak new hiring occurred in engineering in 1976, while that peak will not be reached until 1980 for the mathematical, life, and social sciences. New hiring in the physical sciences will not reach its peak until 1989, when other fields will pull out of the mid-'80's slump. All fields will experience marked declines in the 1990's. These declines will be reversed in the later 1990's if the birth rate picks up as is predicted by the Census. It is also at this time that the hiring bulge of the 1960's will begin to have worked its way through the system to retirement.

Taken from 1980, the largest relative declines in the 1980's will be experienced by the social sciences, followed by life sciences, and mathematical sciences. These relative declines are presented in Table 7.6.

As has been mentioned earlier, these patterns of new hiring result from the interaction of faculty demography, faculty transition rates, and changes in student demand. The sources of new hiring demand by field are examined separately in Figures 7.3A to 7.3E. All fields experience similar changes in the desired stock due to changes in student demand. The contribution of non-tenured attrition varies considerably across fields. This contribution results both from the attrition rate and from the size of the non-tenured population to which it is applied. High non-tenured attrition rates in physical sciences, for example, are the explanation for

TABLE 7.3

DEMAND FOR STOCKS BY FIELD RELATIVE TO 1975 DEMAND

Year	Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
1975	1.0000	1.0000	1.0000	1.0000	1.0000
1976	1.0281	1.0009	1.1846	1.0419	1.0050
1977	1.0565	1.0127	1.2788	1.0866	1.0146
1978	1.0910	1.0281	1.3667	1.1290	1.0241
1979	1.1311	1.0468	1.3909	1.1764	1.0385
1980	1.1684	1.0634	1.4120	1.2203	1.0503
1981	1.1995	1.0714	1.4216	1.2536	1.0539
1982	1.2275	1.0765	1.4282	1.2820	1.0546
1983	1.2386	1.0708	1.4195	1.2967	1.0457
1984	1.2487	1.0604	1.4048	1.3046	1.0319
1985	1.2446	1.0407	1.3778	1.2993	1.0097
1986	1.2233	1.0229	1.3542	1.2771	.9925
1987	1.2155	1.0164	1.3456	1.2690	.9862
1988	1.2184	1.0188	1.3488	1.2720	.9885
1989	1.2294	1.0280	1.3610	1.2834	.9974
1990	1.2132	1.0145	1.3431	1.2666	.9843
1991	1.1849	.9908	1.3118	1.2370	.9614
1992	1.1611	.9709	1.2854	1.2122	.9420
1993	1.1481	.9600	1.2710	1.1986	.9315
1994	1.1443	.9569	1.2668	1.1947	.9284
1995	1.1372	.9509	1.2589	1.1872	.9227
1996	1.1438	.9564	1.2662	1.1941	.9280
1997	1.1614	.9711	1.2857	1.2125	.9422
1998	1.1991	1.0027	1.3275	1.2519	.9729
1999	1.2388	1.0358	1.3714	1.2933	1.0050
2000	1.2801	1.0704	1.4171	1.3364	1.0386

TABLE 7.4

TOTAL FACULTY DEMAND BY FIELDS

Year	Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
1975	18,790	24,652	17,630	68,251	64,471
1976	19,317	24,674	20,885	71,112	64,795
1977	19,852	24,964	22,545	74,161	65,414
1978	20,499	25,344	24,095	77,052	66,022
1979	21,252	25,807	24,522	80,291	66,954
1980	21,954	26,214	24,893	83,285	67,712
1981	22,539	26,413	25,063	85,562	67,944
1982	23,065	26,537	25,180	87,499	67,993
1983	23,273	26,398	25,025	88,498	67,416
1984	23,462	26,141	24,766	89,041	66,527
1985	23,385	25,654	24,290	88,677	65,098
1986	22,985	25,216	23,875	87,161	63,985
1987	22,640	25,056	23,724	86,610	63,581
1988	22,894	25,115	23,779	86,813	63,730
1989	23,100	25,341	23,994	87,596	64,305
1990	22,797	25,009	23,679	86,445	63,460
1991	22,265	24,425	23,126	84,430	61,980
1992	21,817	23,934	22,661	82,731	60,733
1993	21,573	23,666	22,408	81,806	60,054
1994	21,507	23,588	22,334	81,536	59,853
1995	21,368	23,442	22,195	81,030	59,484
1996	21,492	23,577	22,324	81,499	59,828
1997	21,822	23,940	22,667	82,751	60,748
1998	22,532	24,718	23,403	85,441	62,722
1999	23,277	25,535	24,177	88,266	64,796
2000	24,053	26,387	24,984	91,211	66,958

FIGURE 7.2

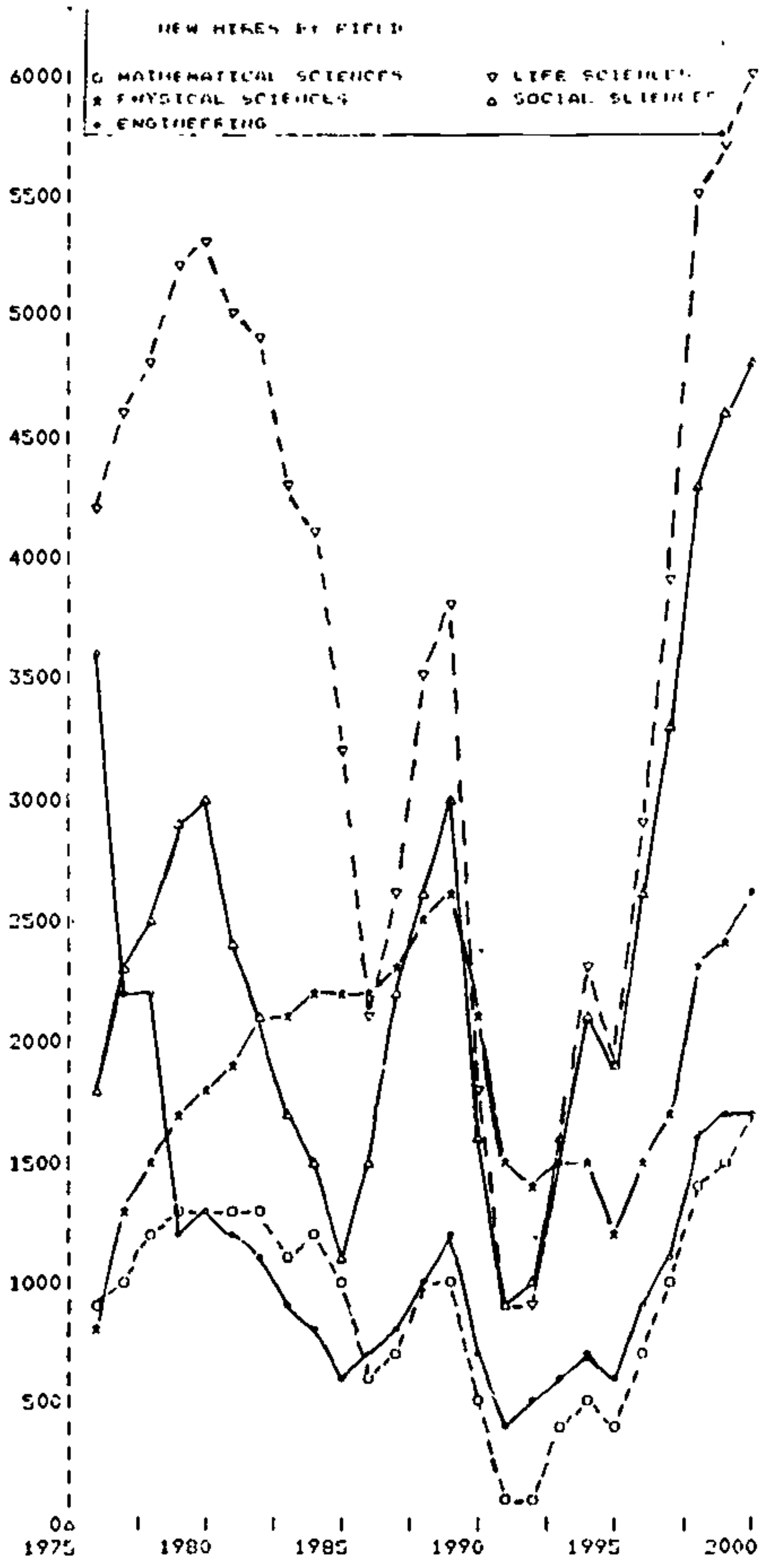

NEW HIRES BY FIELD
MATHEMATICAL SCIENCES
PHYSICAL SCIENCES
ENGINEERING
LIFE SCIENCES
SOCIAL SCIENCES
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1975
1980
1985
1990
1995
2000

TABLE 7.5

NEW HIRES BY FIELD

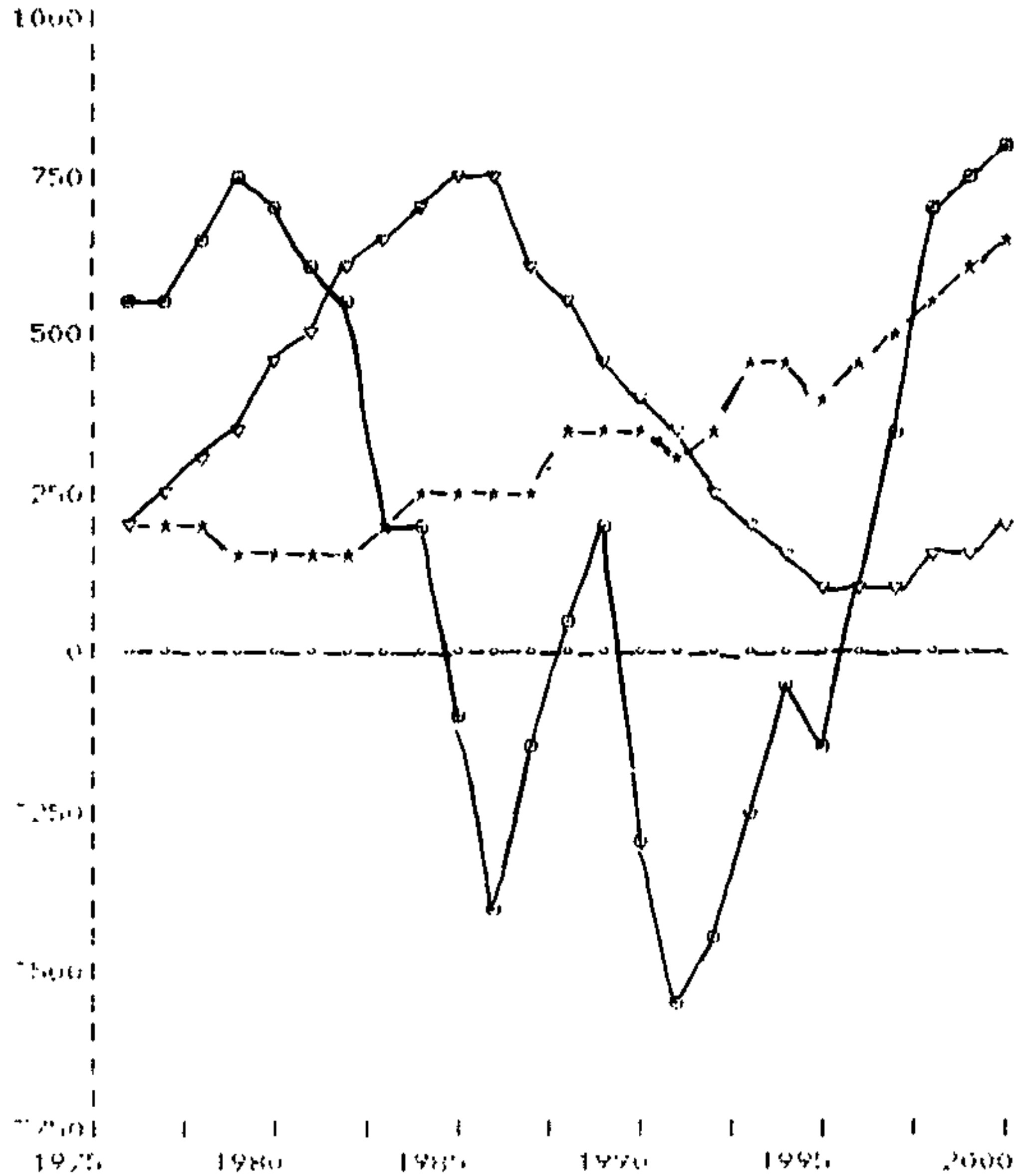
Year	Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
1975	0	0	0	0	0
1976	938	832	3,645	4,247	1,822
1977	978	1,253	2,190	4,623	2,271
1978	1,153	1,452	2,192	4,755	2,459
1979	1,285	1,680	1,229	5,246	2,922
1980	1,300	1,838	1,292	5,330	2,964
1981	1,251	1,885	1,209	4,995	2,401
1982	1,289	2,095	1,116	4,903	2,116
1983	1,059	2,096	893	4,348	1,690
1984	1,160	2,188	774	4,056	1,495
1985	962	2,176	643	3,217	1,124
1986	578	2,165	663	2,136	1,522
1987	717	2,349	849	2,645	2,202
1988	952	2,542	1,013	3,477	2,620
1989	1,017	2,617	1,170	3,816	2,994
1990	456	2,078	680	1,804	1,598
1991	125	1,542	351	888	938
1992	150	1,446	468	866	1,044
1993	390	1,487	572	1,577	1,591
1994	543	1,464	672	2,319	2,140
1995	430	1,222	618	1,916	1,907
1996	705	1,516	856	2,908	2,634
19	966	1,739	1,114	3,937	3,330
1998	1,389	2,310	1,600	5,483	4,303
1999	1,502	2,433	1,670	5,715	4,563
2000	1,657	2,597	1,744	5,965	4,779

TABLE 7.6

NEW HIRING RELATIVE TO 1976

Year	Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
1976	1.00	1.00	1.00	1.00	1.00
1977	1.04	1.51	.60	1.09	1.25
1978	1.23	1.75	.60	1.12	1.35
1979	1.37	2.02	.34	1.24	1.60
1980	1.39	2.21	.35	1.26	1.63
1981	1.33	2.26	.33	1.18	1.32
1982	1.37	2.52	.31	1.15	1.16
1983	1.13	2.52	.24	1.02	.93
1984	1.24	2.63	.21	.96	.82
1985	1.03	2.61	.18	.76	.62
1986	.62	2.60	.18	.50	.84
1987	.76	2.82	.23	.62	1.21
1988	1.01	3.06	.28	.82	1.44
1989	1.08	3.15	.32	.90	1.64
1990	.49	2.50	.19	.42	.88
1991	.13	1.85	.10	.21	.51
1992	.16	1.74	.13	.20	.57
1993	.42	1.79	.16	.37	.87
1994	.58	1.76	.18	.55	1.17
1995	.46	1.47	.17	.45	1.05
1996	.75	1.82	.23	.68	1.45
1997	1.03	2.09	.31	.93	1.83
1998	1.48	2.78	.44	1.29	2.36
1999	1.60	2.92	.46	1.35	2.50
2000	1.77	3.12	.48	1.40	2.62

FIGURE 7.3A

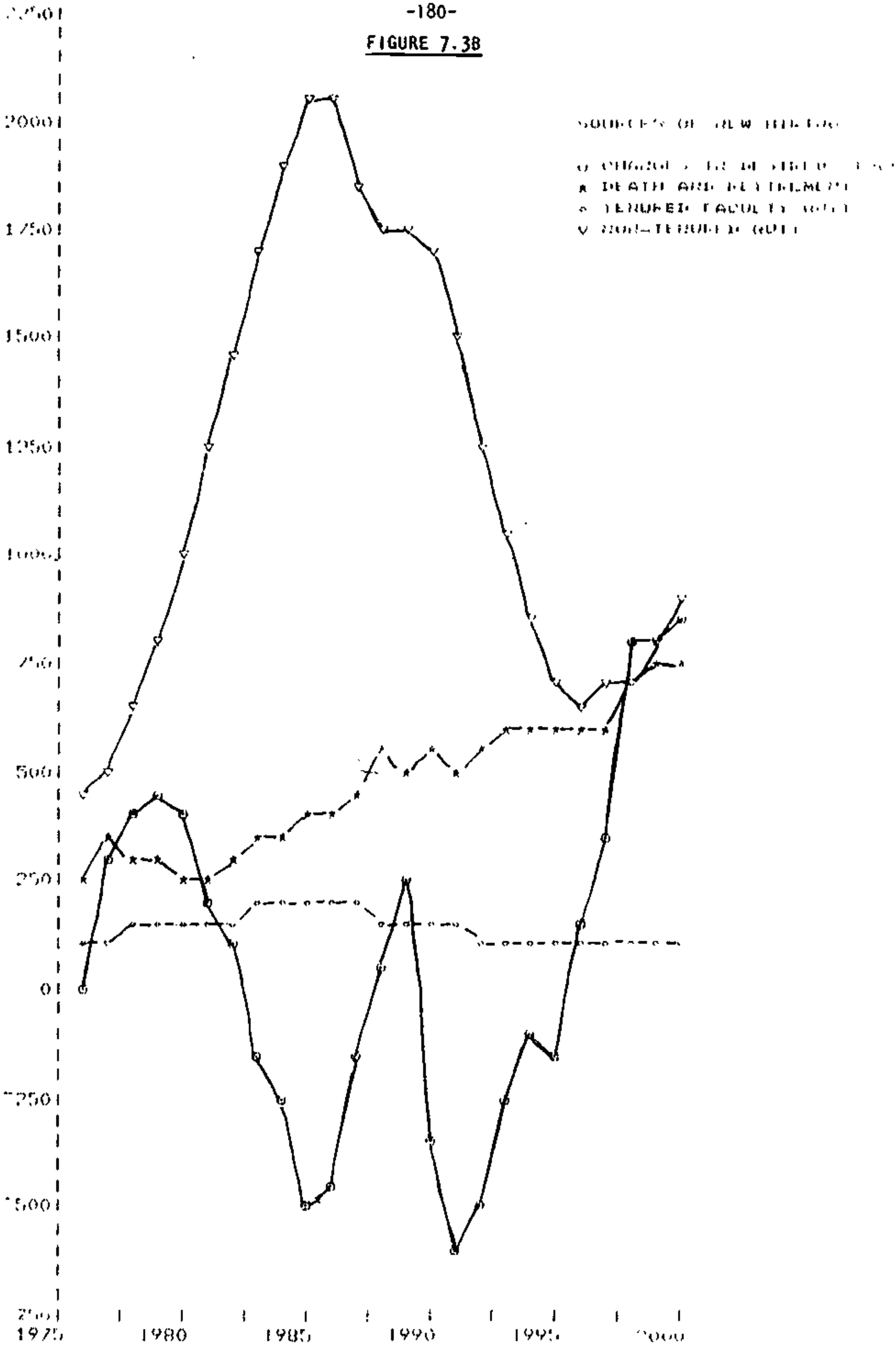


MATHEMATICAL SCIENCES

SOURCES OF NEW HIRES

O CHANGES IN DESIRED STOCK
* DEATH AND RETIREMENT
+ TENURED FACULTY QUIT
V NON TENURED QUITS

FIGURE 7.38



DEATH AND
TENURED FACULTY
2000
1750
1500
1250
500
250
0
1975
1980
1985
1990
1995

FIGURE 7.3C

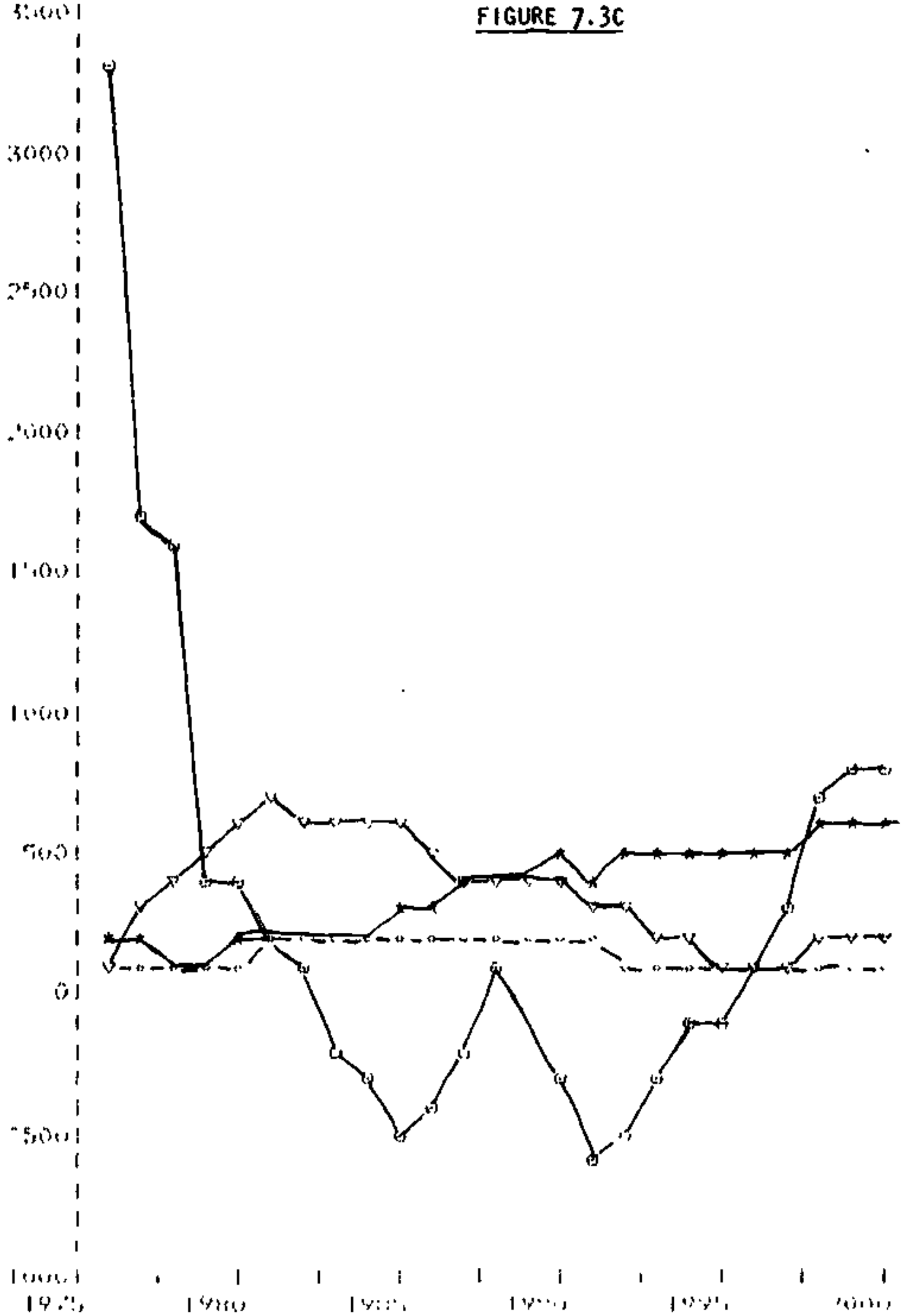

3500
3000
2500
2000
1500
1000
500
0
-500
-1000
1975
1980
1985
1990
1995
2000

FIGURE 7.3D

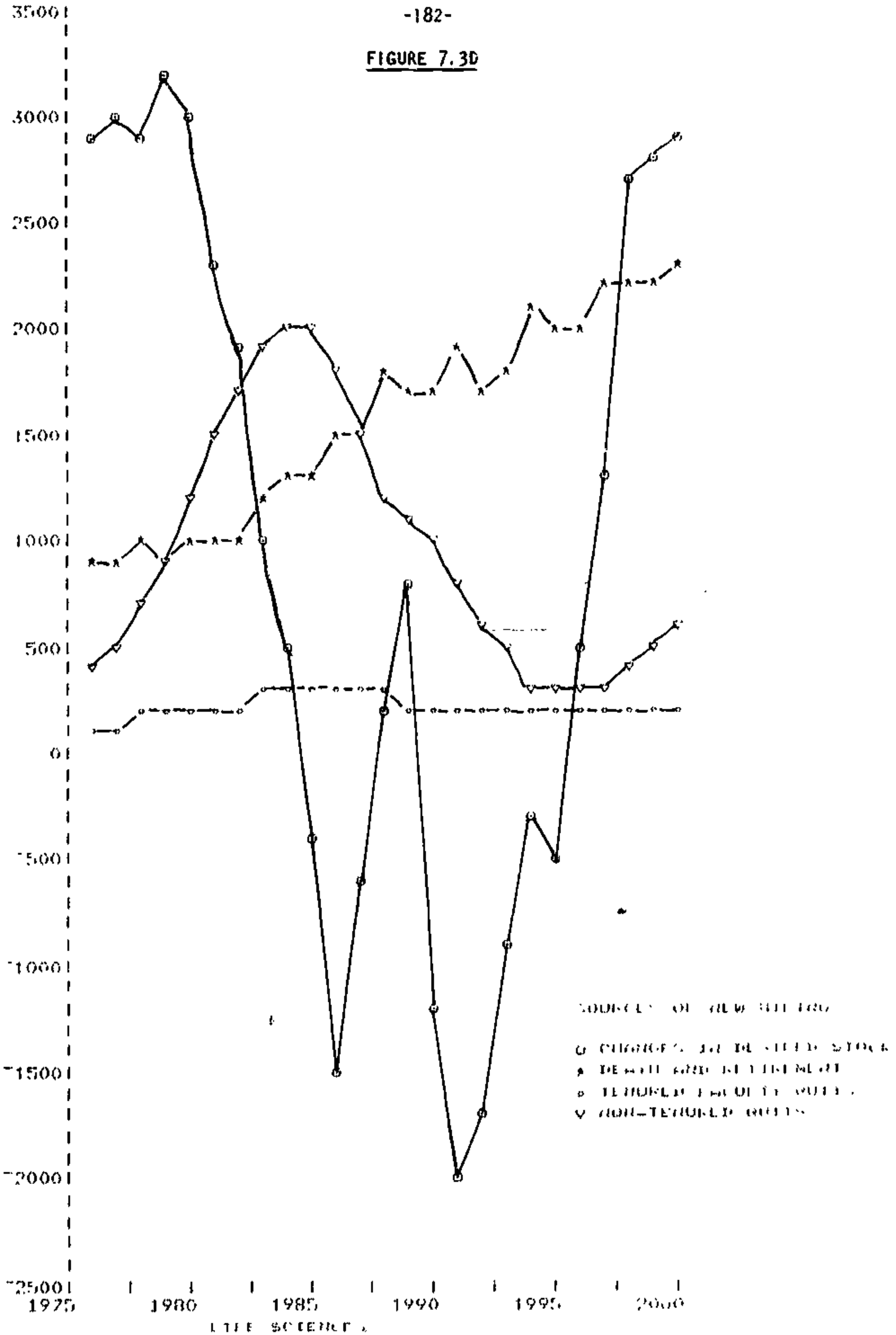
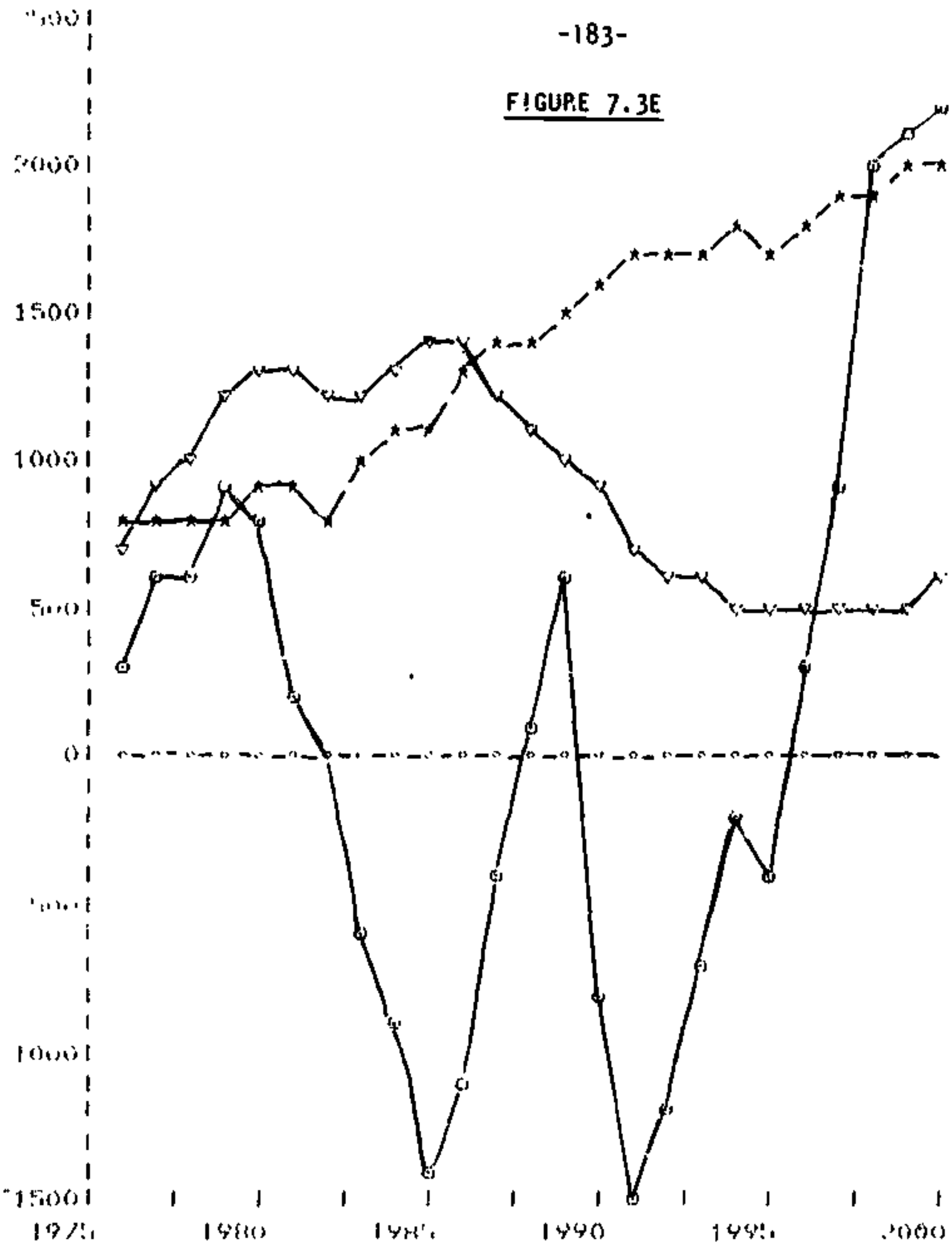

3500
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
1975
1980
1985
1990
1995
2000

FIGURE 7.3E



SOCIAL SCIENCES

SOURCES OF NEW HIRING

O CHANGES IN DESIRED STOCK
* DEATH AND RETIREMENT
o TENURED FACULTY QUITS
V NON-TENURED QUITS

the relatively favorable new hiring projection for this field during the 1980's. Such a "favorable" experience, however, could also be called a "revolving door." For all fields during the 1980's, the revolving door is the principal source of new hiring. In the late 1980's and 1990's, death and retirement play an increasingly important part as the faculty ages.

B. Young Faculty

The ratio of young to total faculty is shown in Figure 7.4 and Table 7.7 for the separate fields. Engineering, which grew most rapidly in the late 1970's, maintains a young faculty share of close to 40 percent until 1982 when the cumulative effect of new hiring cutbacks becomes evident. The other fields show declining young faculty ratios until 1980. These ratios then rise in the physical and life sciences, but continue to decline in the mathematical and social sciences. The ratio declines in the life sciences, as well, after 1982. By the early 1990's, with the exception of the physical sciences, young faculty ratios have declined by almost 20 percentage points or more in all fields.

The high non-tenured attrition rate for the physical sciences and the relatively low tenure rates result in very few physical scientists becoming tenured. The result is a rising young faculty ratio and a declining tenure ratio as retiring tenured faculty are not replaced by faculty who have been promoted to tenure.[4/]

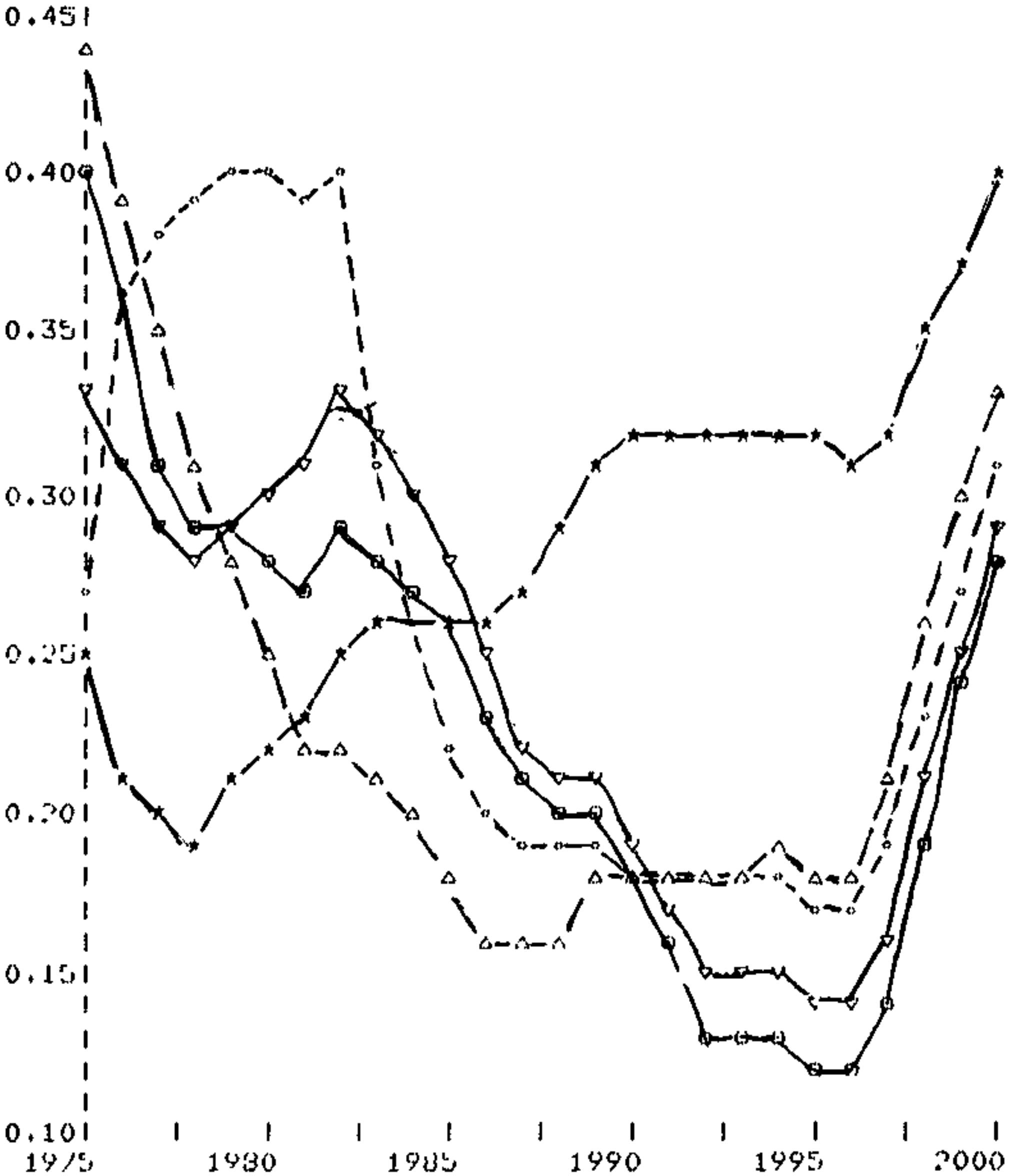
C. The Physical Sciences

The physical sciences show a projected pattern of new hiring so different from the other fields that the sources of these surprising results should be further explored. As mentioned above, the sources of this divergent experience are high non-tenured attrition rates and low rates of promotion to tenure, which mean that young faculty are exposed to the high attrition rates for a relatively longer time. The attrition rates are a characteristic of the CHR data. The age-specific promotion rates are estimated directly from the data. It is possible, however, that our

---

[4/] It is also possible that tenure rates may increase in response to this situation.

FIGURE 7.4



FRACTION OF FACULTY WHICH IS OF ACADEMIC AGE LESS THAN EIGHT

O MATHEMATICAL SCIENCES ∇ LIFE SCIENCES
★ PHYSICAL SCIENCES △ SOCIAL SCIENCES
◇ ENGINEERING

TABLE 7.7

FRACTION OF FACULTY WHICH IS OF ACADEMIC AGE LESS THAN EIGHT

Year	Mathematical Sciences	Physical Sciences	Engineering	Life Sciences	Social Sciences
1975	.3985	.2541	.2700	.3278	.4414
1976	.3555	.2146	.3579	.3064	.3917
1977	.3131	.2011	.3772	.2926	.3480
1978	.2918	.1948	.3941	.2830	.3066
1979	.2911	.2057	.3957	.2909	.2805
1980	.2837	.2198	.3954	.2972	.2510
1981	.2720	.2316	.3925	.3059	.2249
1982	.2869	.2513	.4021	.3270	.2174
1983	.2775	.2585	.3113	.3152	.2110
1984	.2717	.2607	.2636	.2993	.1979
1985	.2558	.2588	.2152	.2770	.1786
1986	.2271	.2578	.1966	.2457	.1621
1987	.2079	.2689	.1862	.2220	.1574
1988	.2029	.2894	.1861	.2126	.1649
1989	.2013	.3114	.1945	.2086	.1806
1990	.1858	.3203	.1920	.1909	.1825
1991	.1571	.3169	.1812	.1675	.1787
1992	.1345	.3160	.1794	.1496	.1799
1993	.1321	.3199	.1810	.1479	.1842
1994	.1322	.3224	.1808	.1504	.1883
1995	.1204	.3159	.1738	.1411	.1838
1996	.1168	.3126	.1690	.1378	.1841
1997	.1404	.3185	.1881	.1627	.2112
1998	.1885	.3463	.2333	.2089	.2562
1999	.2353	.3724	.2724	.2531	.2990
2000	.2756	.3967	.3065	.2891	.3338

assumption that these observed high non-tenured attrition rates will double in the 1980's will prove inaccurate. This feature of our model is based on the expectation that new faculty in the 1980's, disappointed by relatively poor market conditions, will be more likely to withdraw. But it is possible that the academic market has been weak for physical scientists throughout the 1970's, and hence that new cohorts of physical science Ph.D.'s would be less likely to be further disappointed than earlier cohorts. The difference in the time profile of non-tenured attrition for the physical sciences relative to other fields would have to be substantial, however, since non-tenured attrition rates in the physical sciences are now almost double those in other fields.

V. Conclusions

To a large extent, the results presented in Section IV speak for themselves. Declines in new hiring that could easily be called precipitous are likely to occur in all fields except physical sciences in the 1980's and this decline, after a brief plateau, will continue at least until the mid-1990's. The effect of these declines in new hiring will be a declining young faculty ratio and an aging tenured faculty.

Roy Radner and I have explored elsewhere the effect for the mathematical sciences of assuming that adjustment of hiring to changing student demand be spread over a three-year period (rather than annually, as in the present model) (Kuh and Radner, 1980). We have also looked at the projected experience of research ur /ersities under the assumption that private universities will be in the steady state over the period. The effect of these changes in assumptions is to flatten slightly the peaks and troughs, but they do not disappear.

The projected experience of physical science is worth special consideration since it illustrates that the "young investigator" problem is, in fact, multifaceted. Those fields in which young faculty find reasonable prospects of a career that leads to tenure are also those fields that experience the most severe decline in their share of young investigators. The physical sciences, on the other hand, achieve reasonable young investigator ratios through much higher rates of turnover. The question that is important for policy is whether either of these projected patterns of adjustment is conducive to productive research by young investigators, and what kinds of policies can deal with both facets of the problem. It would seem likely that a policy that would both open up tenure slots in the physical sciences and increase the number of non-tenure positions in other fields would be appropriate. It may also be useful to find out whether the high level of turnover in the physical sciences is due to an active non-academic market that can absorb young faculty who do not get tenure. It may be important to broaden such pathways of mobility in other fields as academic markets become tighter.

Although we have not addressed the point in a paper directed toward the "young investigator problem," it is clear that the obverse of the projections for young faculty is the aging of tenured faculty. Very little research has been done on the processes that relate age and productivity and their outcome.[5/] These processes may differ significantly by field, perhaps reflecting differing "obsolescence rates" of knowledge as compared to the acquisition of highly specialized human capital by faculty members. Further research in this area could help answer the question of whether the projected decline in young faculty is truly a "problem" or simply a demographic fact.

Finally, it seems evident that the 1980's will bring a marked decline in the proportion of young faculty in almost every field. Nor is it clear that the revolving door that is apparent in the physical sciences is an optimal solution. I have discussed policy elsewhere (Radner and Kuh, 1978) and it is discussed in the companion volume to this collection of papers. It is hoped that the discussion can now proceed from consideration of whether there is a problem to consideration and analysis of a variety of policy responses.

[5/] Some research, which uses citation analysis, has been reported in S. Cole, "Age and Scientific Performance," American Journal of Sociology, January, 1979. This report finds little relation between age and productivity. The period studied, however, was a period of tremendous increase in the number of faculty. Whether these findings would hold in a period of decline is an open question.

REFERENCES

Cole, S. Age and Scientific Performance, American Journal of Sociology, January 1979.

Fernandez, L. U.S. Doctorate Faculty after the Boom: Demographic Projections to 1995. Technical Report No. 4, Carnegie Council on Policy Studies in Higher Education, October 1978.

Kuh, C. V. and R. Radner. Projections for Ph.D. Mathematicians in Academia. Final report to the National Science Foundation under Grant SRS77-14817, February 1980.

Klitgard, R. E. The Decline of the Best? Kennedy School of Government Discussion Paper No. 65D, May 1979.

National Research Council, Commission on Human Resources. Doctoral Scientists and Engineers in the United States - 1975 Profile, National Academy of Sciences, Washington, D.C.: 1976.

National Science Foundation. Survey of Manpower Resources for Scientific Activities at Universities and Colleges. Detailed Statistical Tables, Appendix B, Washington, D.C.: January 1975 (NSF 75-329)

Radner, R. and C. V. Kuh. Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000. A report to the Carnegie Council on Policy Studies in Higher Education, October 1978.

APPENDIX

DETAILED PROJECTION RESULTS BY FIELD*

Mathematical Sciences

Physical Sciences

Engineering

Life Sciences

Social Sciences

*Results are reported here for every fifth projected year. A full set of results is available from the author on request.

DETAILED PROJECTION RESULTS BY FIELD

MATHEMATICAL SCIENCES

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1975	1980	1985	1990	1995	2000
Biological Age Distribution of Tenured Faculty						
Ages						
26 - 30	.013	.002	.002	.001	.000	.002
31 - 35	.187	.051	.031	.021	.015	.014
36 - 40	.247	.256	.107	.077	.058	.046
41 - 45	.198	.249	.271	.13[illegible]	.107	.092
46 - 50	.124	.182	.236	.271	.147	.129
51 - 55	.104	.108	.166	.226	.273	.159
56 - 60	.071	.085	.096	.155	.222	.281
61 - 65	.035	.052	.067	.081	.135	.206
66 - 70	.020	.014	.025	.034	.043	.072
Of Non-Tenured Faculty						
Ages						
26 - 30	.205	.241	.210	.185	.149	.266
31 - 35	.451	.397	.401	.363	.296	.379
36 - 40	.189	.220	.230	.244	.263	.183
41 - 45	.088	.078	.099	.114	.149	.086
46 - 50	.033	.033	.036	.056	.076	.045
51 - 55	.013	.012	.015	.022	.042	.023
56 - 60	.008	.005	.005	.009	.016	.012
61 - 65	.006	.003	.003	.004	.007	.005
66 - 70	.006	.002	.001	.002	.002	.001
Median Biological Age						
(Ten Fac)	42.37	44.34	47.57	50.92	54.33	57.34
(Non-Ten)	33.99	34.01	34.51	35.30	36.89	33.81
Faculty of Academic Age Seven or Less						
(Number)	7498	6229	5983	4236	2572	6629
(Fraction)	0.399	0.284	0.256	0.186	0.120	0.276
Faculty Tenure Proportion						
	.675	.699	.728	.775	.820	.690
New Hires						
		1300	962	456	430	1657
Deaths and/or Retirements						
		146	243	330	425	661
Total Number of Faculty						
	18790	21954	23385	22797	21368	24053
Aggregate Quitrates						
(Ten Fac)		.0007	.0009	.0007	.0005	.0005
(Non-Ten)		.0691	.1151	.0745	.0303	.0322
Promotion Rates						
		.07[illegible]	.0698	.0917	.0982	.0583
Aggregate Death and Retirement Rates						
		.0069	.0104	.0143	.0198	.0284

DETAILED PROJECTION RESULTS BY FIELD

PHYSICAL SCIENCES

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1975	1980	1985	1990	1995	2000
Biological Age Distribution of Tenured Faculty						
Ages						
26 - 30	.003	.001	.001	.001	.001	.001
31 - 35	.083	.014	.010	.010	.014	.018
36 - 40	.206	.143	.039	.032	.047	.077
41 - 45	.229	.231	.174	.060	.062	.112
46 - 50	.166	.226	.243	.198	.079	.096
51 - 55	.146	.155	.226	.261	.219	.095
56 - 60	.097	.132	.151	.236	.276	.230
61 - 65	.050	.078	.114	.141	.221	.255
66 - 70	.019	.019	.042	.060	.081	.117
Of Non-Tenured Faculty						
Ages						
26 - 30	.098	.167	.188	.185	.121	.154
31 - 35	.411	.323	.347	.372	.337	.338
36 - 40	.238	.256	.203	.210	.267	.245
41 - 45	.118	.128	.130	.100	.130	.137
46 - 50	.052	.063	.067	.067	.062	.063
51 - 55	.033	.027	.033	.034	.043	.027
56 - 60	.021	.017	.015	.018	.023	.020
61 - 65	.018	.013	.011	.009	.013	.011
66 - 70	.012	.006	.005	.004	.004	.004
Median Biological Age						
(Ten Fac)	45.55	48.46	51.76	54.56	57.33	58.57
(Non-Ten)	35.89	36.17	35.42	35.11	36.65	36.14
Faculty of Academic Age Seven or Less						
(Number)	6263	5761	6638	8011	7405	10468
(Fraction)	0.254	0.220	0.259	0.320	0.316	0.397
Faculty Tenure Proportion						
	.696	.696	.685	.625	.594	.486
New Hires						
		1838	2176	2078	1222	2597
Deaths and/or Retirements						
		270	389	542	598	775
Total Number of Faculty						
	24652	26214	25654	25009	23442	26387
Aggregate Quitrates						
(Ten Fac)		.0084	.0112	.0089	.0061	.0061
(Non-Ten)		.1312	.2496	.1814	.0722	.0714
Promotion Rates						
		.063	.0334	.0335	.0414	.0451
Aggregate Death and Retirement Rates						
		.0105	.0149	.0214	.0253	.0303

DETAILED PROJECTION RESULTS BY FIELD

ENGINEERING

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1975	1980	1985	1990	1995	2000
Biological Age Distribution of Tenured Faculty						
Ages						
26 - 30	.003	.003	.001	.001	.000	.001
31 - 35	.068	.031	.026	.012	.011	.015
36 - 40	.227	.120	.106	.062	.042	.047
41 - 45	.223	.239	.162	.150	.098	.083
46 - 50	.187	.212	.233	.185	.184	.130
51 - 55	.167	.170	.188	.235	.202	.209
56 - 60	.088	.146	.144	.180	.237	.211
61 - 65	.031	.067	.109	.122	.161	.214
66 - 70	.005	.011	.031	.054	.064	.089
Of Non-Tenured Faculty						
Ages						
26 - 30	.068	.124	.073	.088	.068	.125
31 - 35	.366	.372	.250	.220	.191	.270
36 - 40	.273	.267	.310	.227	.211	.201
41 - 45	.134	.141	.201	.222	.182	.137
46 - 50	.076	.051	.099	.136	.169	.097
51 - 55	.047	.025	.037	.067	.104	.086
56 - 60	.024	.012	.018	.025	.052	.054
61 - 65	.011	.006	.009	.011	.018	.025
66 - 70	.002	.001	.002	.003	.005	.005
Median Biological Age						
(Ten Fac)	45.45	48.22	50.40	53.02	55.15	56.37
(Non-Ten)	36.60	36.06	38.72	40.29	41.79	38.51
Faculty of Academic Age Seven or Less						
(Number)	4759	9843	5227	4545	3858	7659
(Fraction)	0.270	0.395	0.215	0.192	0.174	0.307
Faculty Tenure Proportion						
	.725	.559	.631	.627	.628	.524
New Hires						
		1292	643	680	618	1744
Deaths and/or Retirements						
		178	320	456	521	604
Total Number of Faculty						
	17630	24893	24290	23679	22195	24984
Aggregate Quitrates						
(Ten Fac)		.0107	.0143	.0114	.0078	.0078
(Non-Ten)		.055	.0617	.0412	.0157	.0212
Promotion Rates						
		.0565	.0579	.06	.0483	.043
Aggregate Death and Retirement Rates						
		.0072	.0129	.019	.0233	.025

DETAILED PROJECTION RESULTS BY FIELD

LIFE SCIENCES

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

Biological Age Distribution of Tenured Faculty

Ages	1975	1980	1985	1990	1995	2000
26 - 30	.003	.001	.001	.001	.000	.001
31 - 35	.092	.022	.019	.011	.007	.010
36 - 40	.156	.166	.078	.063	.041	.035
41 - 45	.194	.187	.211	.128	.108	.082
46 - 50	.180	.192	.197	.236	.16[illegible]	.145
51 - 55	.159	.167	.183	.201	.254	.188
56 - 60	.126	.140	.151	.176	.204	.265
61 - 65	.073	.098	.112	.127	.157	.187
66 - 70	.017	.026	.049	.057	.066	.086

Of Non-Tenured Faculty

Ages	1975	1980	1985	1990	1995	2000
26 - 30	.078	.109	.074	.061	.051	.102
31 - 35	.398	.324	.283	.217	.166	.283
36 - 40	.241	.294	.287	.259	.217	.206
41 - 45	.120	.142	.193	.211	.208	.139
46 - 50	.072	.068	.092	.142	.166	.110
51 - 55	.046	.031	.039	.065	.112	.078
56 - 60	.027	.018	.017	.028	.052	.053
61 - 65	.015	.011	.010	.012	.021	.023
66 - 70	.005	.003	.004	.005	.006	.006

Median Biological Age

	1975	1980	1985	1990	1995	2000
(Ten Fac)	47.56	49.13	50.84	52.36	54.65	56.84
(Non-Ten)	36.36	36.96	38.27	40.27	42.53	38.[illegible]9

Faculty of Academic Age Seven or Less

	1975	1980	1985	1990	1995	2000
(Number)	22372	24752	24568	16502	11433	26370
(Fraction)	0.328	0.297	0.277	0.191	0.141	0.289

Faculty Tenure Proportion

1975	1980	1985	1990	1995	2000
.665	.618	.629	.653	.679	.579

New Hires

1975	1980	1985	1990	1995	2000
	5330	3217	1804	1916	5965

Deaths and/or Retirements

1975	1980	1985	1990	1995	2000
	981	1283	1732	1995	2251

Total Number of Faculty

1975	1980	1985	1990	1995	2000
68251	83285	88677	86445	81030	91211

Aggregate Quitrates

	1975	1980	1985	1990	1995	2000
(Ten Fac)		.0039	.0052	.0041	.0026	.0028
(Non-Ten)		.0387	.0596	.0316	.0101	.0178

Promotion Rates

1975	1980	1985	1990	1995	2000
	.0724	.0584	.0749	.0641	.0497

Aggregate Death and Retirement Rates

1975	1980	1985	1990	1995	2000
	.0122	.0144	.0198	.0245	.0255

DETAILED PROJECTION RESULTS BY FIELD

SOCIAL SCIENCES

TOTAL FACULTY: DOCTORATE AND NON-DOCTORATE

Projected Years

	1975	1980	1985	1990	1995	2000
Biological Age Distribution of Tenured Faculty						
Ages						
26 - 30	.012	.002	.001	.001	.001	.002
31 - 35	.120	.043	.022	.013	.016	.024
36 - 40	.170	.190	.086	.051	.047	.060
41 - 45	.185	.192	.217	.111	.078	.088
46 - 50	.162	.181	.198	.238	.131	.102
51 - 55	.162	.150	.178	.210	.260	.146
56 - 60	.106	.139	.141	.183	.222	.273
61 - 65	.069	.079	.116	.130	.173	.208
66 - 70	.015	.023	.040	.064	.073	.096
Of Non-Tenured Faculty						
Ages						
26 - 30	.126	.141	.103	.153	.130	.172
31 - 35	.374	.335	.342	.363	.323	.376
36 - 40	.213	.263	.262	.234	.271	.236
41 - 45	.123	.122	.146	.116	.137	.118
46 - 50	.076	.066	.071	.069	.068	.055
51 - 55	.047	.025	.038	.033	.039	.023
56 - 60	.023	.021	.019	.017	.018	.012
61 - 65	.013	.012	.013	.010	.010	.006
66 - 70	.004	.004	.006	.005	.004	.002
Median Biological Age						
(Ten Fac)	46.41	47.99	50.35	52.94	55.32	57.58
(Non-Ten)	36.00	36.36	36.84	35.75	36.71	35.29
Faculty of Academic Age Seven or Less						
(Number)	28461	16999	11627	11579	10933	22348
(Fraction)	0.441	0.251	0.179	0.182	0.184	0.334
Faculty Tenure Proportion						
	.642	.742	.816	.798	.783	.646
New Hires						
		2964	1124	1598	1907	4779
Deaths and/or Retirements						
		896	1149	1572	1735	2020
Total Number of Faculty						
	64471	67712	65098	63460	59484	66958
Aggregate Quitrates						
(Ten Fac)						
(Non-Ten)		.073	.1037	.0653	.0408	.0281
Promotion Rates						
		.1168	.0834	.0777	.0806	.0673
Aggregate Death and Retirement Rates						
		.0134	.0173	.0245	.029	.0312

CHAPTER VIII

AGE AND SCIENTIFIC PRODUCTIVITY: A CRITICAL REVIEW

Barbara F. Reskin
Indiana University

For the past half century social scientists have periodically considered the effects of scientists' age on their performance. Studies have focused on specific disciplines or subgroups, such as eminent scientists or those employed in various organizational settings, and have examined several different measures of performance. Extensive, albeit methodologically inadequate, study has failed to turn up any convincing evidence of a strong, simple relationship between age and the productivity of individual scientists. This relationship still awaits theoretically informed and methodologically rigorous investigation.

Most empirical work on age and performance has been prompted by two concerns: general interest in the impact of aging on various kinds of behavior and specific policy issues related to enhancing scientific output (Taylor and Barron, 1963; Pelz and Andrews, 1966). In spite of sociological, psychological and economic theories of science or creativity that imply hypotheses about the relationship between age and productivity, little of the empirical work is theoretically informed (Pelz and Andrews' work is an exception). In the first section of this review, I summarize the theoretical bases for a relationship between age and scientific productivity and present some models for the form of the relationship. In the second section, the rather limited evidence in the literature for such a relationship is evaluated. I then discuss methodological problems that beset research on this topic. Finally, I hazard some tentative conclusions about the relationship in question.

I. Theoretical Analysis

Assumptions about the Impact of Aging on Performance

In view of the atheoretical nature of most inquiries into the age-productivity relationship, the lack of consensus even on issues as fundamental as the direction or form of the relationship is not surprising. Conflicting assumptions that aging impairs performance and that performance improves with experience--and hence with age--both enjoy wide support. Laypersons and practicing scientists alike often assume that aging inherently impairs many kinds of human performance, either because it causes psychological or mental decline or because it leads to personality changes that interfere with certain kinds of performance.[1/] (For example, some believe that old people become "set in their ways" and resist new ideas.) Although the corollary that youth is characterized by greater mental vigor does not necessarily follow, it is probably even more widely accepted. This belief that aging adversely affects performance constitutes the major basis for the assumption of a negative relationship between scientists' age and their productivity.

The premise that performance improves with experience implies the opposite effect of age. Since age is highly correlated with professional experience, scientists' performance should improve over time. That scientists regard breakthroughs by young researchers as remarkable implies that they accept the assumption of a positive impact of experience.

But experience can also be a handicap to scientific innovation. Naive young scientists may pursue ideas that more experienced scientists would reject out of hand. As Nobel Laureate Chen Ning Yang observed, "As you get older, you get less daring. You have seen so much--therefore, for every new thought you have, you immediately marshal a large number of counter-arguments." (Pelz and Andrews, 1966, p. 197). This view is manifest

---

[1/] Gerontologists have assessed these assumptions, but a review of the extensive gerontological literature on the effects of age on performance is beyond the scope of this paper, which argues that scientific productivity is determined largely by the social context of research.

in Kuhn's (1962) theory of scientific revolutions, which holds that scientists who create revolutionary new paradigms are often outsiders--either young or new to their field--who are not hampered by viewing phenomena in the established way. Older scientists may also be constrained by their vested stake in traditional views (Barber, 1961, p. 602; Hagstrom, 1965, p. 284). Hence, Kuhn follows Planck (in Zuckerman and Merton, 1972) in contending that scientific crises are resolved not by converting the adherents of the older paradigm to the new one, but through their ultimate replacement by the new generation.

If the beliefs about the negative impact of aging and the positive one of experience both have merit, the effects could cancel each other out or they could operate separately at opposite ends of the professional life cycle, generating a curvilinear relationship between age and performance. In reality, it is sociologically naive to expect either pattern. Any effect of age is necessarily confounded with a variety of other factors that affect scientific productivity. A fruitful theory of the impact of age on scientists' performance must incorporate sociological and psychological theories of scientific productivity.

Implications of Psychological Theories for the Age-Productivity Relationship

Psychological approaches to scientific productivity (or, more broadly, to creativity) emphasize intellectual ability, motivation, and other personality traits. Although intelligence probably does not vary by age (Pelz and Andrews, 1966, p. 175; Blackburn, 1972, p. 22),[2/] a case might be made that level of motivation declines as scientists age. The need to work hard to achieve job security or tenure or to prove oneself--sometimes occasioned by the belief that scientists who have not made it by the time they are 35 or 40 will never do so--diminishes over time. Older scientists' willingness to put in long hours and to defer personal gratification may decline either because they have achieved their goals or forsaken them (Pelz and Andrews, 1966). Although Pelz and Andrews observed that motivation affected scientists' productivity, they also found that aging did

[2/] In addition, measured ability does not distinguish more and less productive scientists (Taylor and Barron, 1963; Bayer and Folger, 1966, pp. 381-90; J. Cole, 1974, p. 40).

not inevitably lead to reduced motivation. Vroom (1964, p. 204) reported that workers' motivation enhanced their output, unless it was accompanied by a high level of anxiety. Younger scientists' anxiety about tenure or professional security might depress the beneficial effect of their greater motivation, whereas older scientists, less in need of proving themselves, should be less hampered by anxiety.

Another personality trait some believe necessary for scientific innovation is the willingness to take risks or stands on controversial issues (Blackburn, 1972, p. 16). Older scientists, having established their reputations and obtained job security, may be more willing to take such risks or simply be more self-confident (Pelz and Andrews, 1966, p. 210).

Cole and Cole (1973) pointed to the importance of sheer stamina, which might reasonably be expected to decline as scientists grow older. The amount of time college and university faculty spent at research dropped with increasing years of experience (Tuckman, 1976), although this does not necessarily imply reduced stamina. In any case, the relationship between scientific productivity and number of hours scientists work is weak (Fulton and Trow, 1974, p. 62; Hargens, 1978).[3/]

Implications of Sociological Theories for the Age-Productivity Relationship

The importance of professional socialization to research norms and techniques is generally accepted (Crane, 1965; Zuckerman, 1977), but it is probably important only for recently trained scientists (Reskin, 1979). Young scientists tend to be better informed on the current state of their field (Zuckerman and Merton, 1972, p. 306). This should help them identify and move into emerging problem areas and generally enhance their chance of making major contributions. Furthermore, because most new doctorates come from the top graduate institutions, they are more likely to have been exposed to the most up-to-date techniques in their fields.

[3/] Sociologists ventured into the domain of psychology in proposing the importance of a "propensity to publish" (Hargens, Reskin and Allison, 1976) or a "sacred spark"--an inner drive that compels some scientists to do research regardless of whether they receive external rewards (Cole and Cole, 1973, p. 114), but there is no theoretical reason to expect either to vary by age.

But socialization is not sufficient to maintain productivity (Hagstom, 1965). Sociological studies have assembled considerable evidence that scientists' performance at any point in their careers is primarily a function of the availability of resources, the extent of alternative role demands, expectations about their performance, and the existence of both material and professional rewards (Hagstrom, 1965, p. 28; Reskin, 1977). This combination of expectations, resources, and rewards that sociologists term the "reward structure" frequently depends on the organizational setting in which scientists are located. Cole and Cole (1973, pp. 119-122) posited a feedback relationship between productivity, recognition, and resources wherein collegial recognition of published work demonstrates a scientist's merit to those who distribute professional resources (appointments, grants, assistance). These resources both reinforce past performance and facilitate future productivity. This process of "accumulative advantage" should generate an improved fit between resources, productivity, and recognition as scientists age (Allison and Stewart, 1974). Allison and Stewart (1974) and Long (1978) support a qualified version of the accumulative-advantage hypothesis. Its relevance for the age-productivity relationship is clear: among productive scientists, productivity should increase over time: for unproductive scientists or those whose contributions do not elicit recognition and rewards, increased age should be associated with declining productivity. Although physiological effects of aging are not ruled out, they should be small relative to those of the scientific reward structure.

Economists invoke the diminishing economic returns to publications as scientists age as one basis for expecting productivity to decline for older scientists (Tuckman, 1976). However, the supposition that researchers are motivated primarily by economic considerations rather than professional rewards (such as formal or informal collegial recognition) is debatable. Scientists primarily oriented toward monetary rewards probably choose more lucrative jobs in private enterprise over positions in academic and non-profit research organizations.

Scientists' social position also affects the likelihood that they will change their research emphasis or point of view in response to innovations (Hagstrom, 1965, p. 284). Younger scientists lack extensive personal ties that constrain them from accepting a new point of view, so they are better able to exploit scientific breakthroughs.

Competing demands on scientists' time should play a large role in their productivity. The midcareer productivity slump observed in some studies (e.g., Pelz and Andrews, 1966) has been attributed to the administrative responsibilities established scientists are often persuaded to assume. Nobel Laureates' typical productivity decline is probably due to the numerous professional requests they receive after the prize is conferred (Zuckerman, 1977). The competing demands on researchers' time varies with their age and is probably greatest for scientists in their forties and fifties. Although this leaves many potentially productive years for scientists to resume their research after completing their administrative obligations, their ability to do so will depend on the speed with which their specialty has advanced and changed.

Extraprofessional roles also take scientists' time from their research. Although demands to devote time and energy to one's family are greatest for young scientists, the need to achieve job security partly insulates them from these demands. As scientists achieve professional security, their commitment to familial and other nonscientific roles may increase. Certainly normative support for assigning their work the highest priority diminishes.

The Effect of Scientific Specialty on the Age-Productivity Relationship

Sociologists of science have identified several aspects of scientific specialties that appear to affect scientists' productivity. These include their rates of growth and technological obsolescence, the way in which research work is typically organized, and their degree of codification. A theoretical case can be made that these factors affect the form of any relationship between age and productivity.

Young scientists often enter emerging problem areas in which a considerable amount of work can be produced fairly quickly. However, as progressively more of the questions in an area are solved, the probability of making an important contribution declines. Researchers must then choose between remaining in the area or switching to another with more unsolved problems. Younger scientists may be more likely to respond to stagnation in their research areas--or to opportunities in emerging problem areas--by changing fields (Gieryn, 1979a). They have less invested in their specialty or research area, their broader training facilitates migrating to a new problem area, and they have a longer work life ahead during which the move can pay off. Older, more specialized researchers, on the the other hand, may be deterred from changing fields by their reluctance to compete with either the younger, more recently trained scientists, or the established researchers in the area. The same reasoning would predict differential responses by older and younger scientists to technological obsolescence in their field.

Fields differ in their rates of growth and technological obsolescence. If the above argument that younger scientists are more likely to migrate out of stagnating fields is sound, then the advantage of youth on performance should be greatest in rapidly growing specialties and smallest in those experiencing minimum change.

Specialty differences in the organization of research work may also affect any age-productivity relationship. First, any net effect of age on an individual scientist's performance might be partially masked in fields characterized by collaborative research among scientists at different stages of their careers. Second, the effect of the increasing numbers of pre- and postdoctoral students that successful researchers may attract as they age will depend on whether most research is sole or collaborative. In fields in which research is primarily an individual activity, having several students usually will not facilitate and may even hamper scientists' performance; whereas in fields in which research is a group enterprise, research volume will be enhanced by additional workers. In fact, scientists with one or more postdoctoral fellows to run their labs should be able to take on administrative tasks without a decline in their output.

Finally, specialty differences in degree of codification--that is, the degree of consensus among practitioners on important questions and appropriate research strategies--may affect the age-productivity relationship (Zuckerman and Merton, 1972). In more codified fields, young investigators can more readily identify and attack important problems; hence, they are less hindered by their lack of experience. In less codified fields, on the other hand, lengthy experience may be beneficial, if not essential, for producing important work, and age may provide an important advantage. Because field switching is more difficult in highly codified fields, in such fields younger scientists' greater inclination to migrate to new research areas would not have the hypothesized effect on productivity. Thus, any positive effect of age on productivity based on differential rates of field switching should be greater in less codified fields.

Type of Scientific Performance

The form of the age-productivity relationship will depend on the type of performance at issue. Indeed, a case could be made that the effects of age on sheer volume of productivity and on the quality of contributions would be in opposite directions (and plausible arguments might be made for either direction). Moreover, the forms of both the quantity and quality relationships undoubtedly vary by field. In highly codified fields, if experience does not necessarily provide an increasingly broad view of the discipline, age would be no special advantage in doing work that integrates several disparate research areas. In low-consensus fields, however, scientists with extensive experience can contribute to their discipline through such integrative work.

Impact of the Age Structure on Aggregate Productivity

Up to this point I have considered some theoretical reasons why age might affect the performance of individual scientists. However, even if no individual-level association exists, the age structure of a discipline or research specialty might affect its overall level of growth. For example, if recently trained scientists act as emissaries in bringing new techniques and problems to existing research groups, their absence could depress the vitality or volume of that group's output (National Research Council, 1979).

If an individual-level association does exist and if young scientists are more responsive to developing problem areas (Gieryn, 1979a), a decline in the number of young scientists could impede the rate of scientifc progress.

Models of the Relationship Between Age and Productivity

The above discussion implies that any properly specified model of the age-productivity relationship must take into account several additional variables. Nonetheless, it is instructive to consider the variety of forms the simple relationship between age and productivity might assume. In this section, I present several formal models of that relationship (Figure 8.1). Many of the models were taken from Bayer and Dutton (1977) who present the mathematical form of six models gleaned from their review of the literature. (Their tests of the six models for several disciplines are reported in the following section.) In the equations below, Y represents some measure of scientific performance, X represents age, and Z denotes other predictors of performance.

The simplest model is one in which age and productivity are unrelated either because age has no effect or because any negative effect of age is cancelled out by the positive effect of experience. Hence, productivity is wholly determined by other variables.

$$Y = a + bZ \qquad (1)$$

This and subsequent models are shown in Figure 8.1.

Equations 2 and 3 both reflect the assumption that productivity declines with age. The first (equation 2), which shows a negative linear relationship, lacks a convincing theoretical basis.

$$Y = a - bX \qquad (2)$$

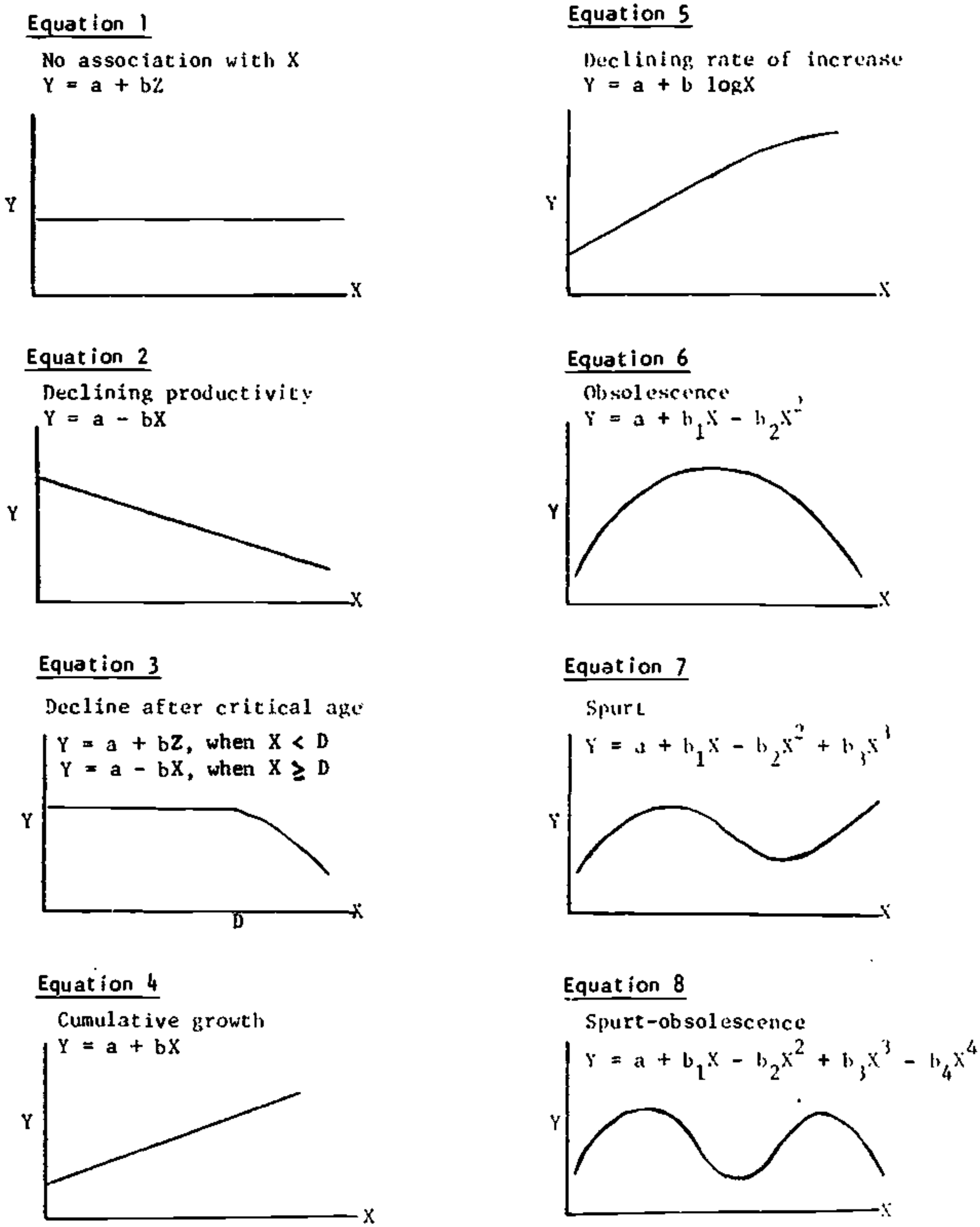
The presupposition that age adversely affects productivity only after some advanced age cannot be captured by a single equation, but would be reflected by a combination of equation 1 (no relationship) and equation 2 (a negative relationship when X is greater than some specified value, D).

$$Y = a + bZ, \text{ where } X < D \qquad (3)$$

$$Y = a - bX, \text{ where } X \geq D$$

The next three models reflect the assumption that experience enhances productivity. The first (equation 4), which Bayer and Dutton (1977) describe as a "cumulative growth" function, shows a positive linear relationship between age and productivity:

$$Y = a + bX \qquad (4)$$



MODELS OF THE AGE-PRODUCTIVITY ASSOCIATION (X=AGE)

FIGURE 8.1

Notice that this model is consistent with the accumulative-advantage hypothesis; although the variation around the regression line would increase as X increases if productive scientists accumulate advantages as they age.

Equation 5 depicts Bayer and Dutton's "declining rate of increase" function, which assumes that the rate at which performance improves with the experience or the accumulation of resources that often accompany increased professional age declines over time. Thus, it reflects the hypothesis that aging per se or psychological changes that accompany aging, such as reduced motivation, increasingly attenuate the positive effect of experience on scientists' performance.[4/]

$$Y = a + b \log X \tag{5}$$

Equation 6, the "obsolescence" model, assumes an absolute decline with age rather than the declining rate of increase assumed in equation 5. In this model, performance improves with age during the first part of scientists' careers and then drops, either because of scientists' reduced vigor or because declining economic or professional returns to performance reduce the incentive to do research.

$$Y = a + b_1X - b_2X^2 \tag{6}$$

Equation 7, which Bayer and Dutton labelled the "spurt" function, reflects the positive effects of experience and academic rewards, while assuming a midcareer drop resulting from increased administrative responsibilities or a post-tenure slump. The bimodal curve assumes a resurgence of productivity and implies no deleterious effects of aging per se.

$$Y = a + b_1X - b_2X^2 + b_3X^3 \tag{7}$$

[4/] Many quite similar functions are possible. For example, Bayer and Dutton (1977) presented the "leveling off" function, an asymptotic function of the form $Y = a + b(1/X)$, which implies that after some age additional years of experience will yield no further payoff in productivity. This is similar to equation 5, but the latter stipulates a declining rate of return to productivity with increasing experience rather than a complete leveling off. The theoretical literature provides no basis to expect the beneficial effect of experience to disappear completely after some particular age.

The final model, shown in equation 8, includes both a midcareer spurt and a decline at the career's end. This "spurt-obsolescence" model incorporates theoretical assumptions of both the negative effects of aging and the postive effects of experience and the academic reward system, while also providing for a midcareer slump associated with specific career events described above.

$$Y = a + b_1X - b_2X^2 + b_3X^3 - b_4X^4 \qquad (8)$$

The bimodal distributions in panels 7 and 8 of Figure 8.1 correspond to the saddle-shaped curve referred to in the review of the empirical studies that follows.

The propriety of a particular model obviously depends in part on the specific performance measure under consideration.

II. Evidence of the Relationship Between Age and Performance

Early work by Lehman (1936, 1944, 1953) supported the commonly held belief that scientific performance declines as scientists age. However, Lehman's work has been criticized on methodological grounds (Dennis, 1956a, 1956b, 1958, 1966; Zuckerman and Merton, 1972; S. Cole, 1979). Rather than comparing the proportions of scientists in each of his age groups who made important discoveries to see whether they diminish over time, Lehman computed the proportion of important discoveries made by scientists of different ages. Thus he implicitly--and erroneously--assumed an equal proportion of scientists in each age group. In fact, it follows from the growth of science over the last two centuries that scientists are disproportionately young and that proportionately more discoveries will be made by young scientists. Lehman also failed to consider the effect of differential longevity on the distribution of achievements by scientists of different ages. Scientists who die young can only be credited with achievements of their youth; had they survived, some would have produced important work at later ages. If all scientists were equally long-lived, Lehman would have observed a more equal distribution of achievements.

Subsequent empirical work was flawed in other ways. Below, in reviewing studies of the relationship between age and productivity, I point out methodological shortcomings that mar much of the literature in this area. After considering evidence for the association based on data aggregated over scientific fields, I examine field-specific studies.

Pelz and Andrews (1966) observed a bimodal distribution for several measures of scientific performance (including "scientific contributions" and published and unpublished papers) for doctoral scientists employed in research and development laboratories. The intervening slump occurred earlier for scientists in research (between ages 45 and 49) than for those in development (ages 50 to 54). Because the researchers found that at least moderate administrative loads did not interfere with sample members' output, they concluded that reduced motivation was more likely than administrative responsibilities to account for the midcareer slump.

Blackburn, Beyhmer and Hall (1978) examined the association among Ph.D. holders who were on college and university faculties. Among those in high-prestige institutions, they observed the bimodal "saddle-shaped" curve which Bayer and Dutton (1977) termed the spurt-obsolescence pattern (equation 8). Productivity peaked for scientists in their late 30's and late 40's, with a slump in the intervening years. However, scientists at lower prestige institutions did not show the bimodal pattern.

In the only study of eminent scientists reviewed here, Zuckerman (1977) presented age-specific annual productivity rates for Nobel Laureates and a matched sample of non-Laureates. Both groups showed the bimodal pattern, although the peaks for the Laureates fell a half a decade later than those for members of the matched sample (and, of course, the Laureates outpublished members of the matched sample at every age).

Discipline-Specific Studies

I discussed above several theoretical reasons why fields might differ in the relationship between age and performance. Unfortunately, our ability to test these predictions about field differences is hampered by the scarcity of comparable studies using similar measures and equivalent samples across scientific disciplines. Only Bayer and Dutton (1977) and S. Cole (1979) provide such analyses. Bayer and Dutton's sample was composed of 5,000 Ph.D.-holding college and university faculty in seven disciplines. The authors tested six models of the age-productivity relationship for several measures of productivity (recent articles, lifetime articles, books, number of works cited in the 1978 Science Citation Index, pure research orientation, time spent in research, number of journal subscriptions and time spent consulting). Cole studied article and citation rates for about 2,500 scientists employed in Ph.D.-granting departments in six fields. Unfortunately, neither study took into account other determinants of productivity besides discipline.

Physics. Bayer and Dutton (1977) report a weak spurt-obsolescence pattern for their physicists' recent publications (see Figure 8.2).[5/] The publication rate of Cole's higher status physicists showed an obsolescence pattern, with article productivity peaking between the ages of 40 and 44 and then declining gradually to about half of the maximum level. Compositional differences between the two samples might account for the discrepancy at the ends of these physicists' careers. The less productive physicists in Bayer and Dutton's more heterogeneous sample might have been more likely to retire from faculty positions at earlier ages. If so, those older physicists remaining would show an apparent upswing toward the end of their careers. Although a nonlinear model provided better fit to Bayer and Dutton's data than a linear one, it must be stressed that age accounted for less than two percent of the variance in productivity, and there is no reason to expect a stronger association in Cole's results.

Allison and Stewart's (1974) aggregate analysis of data for faculty at Ph.D.-granting departments showed increasing inequality in the distribution of scientific productivity among older cohorts of physicists. This is consistent with the accumulative-advantage hypothesis that predicts increasing inequality in the distribution of resources and professional rewards as scientists age and implicitly attributes productivity declines among older scientists to reduced access to resources for research.

[5/] Space limitations preclude presenting results for any other productivity measures. Bayer and Dutton (1977) showed that the patterns for articles and citations typically differed, so these results cannot be generalized to other measures of scientific performance.

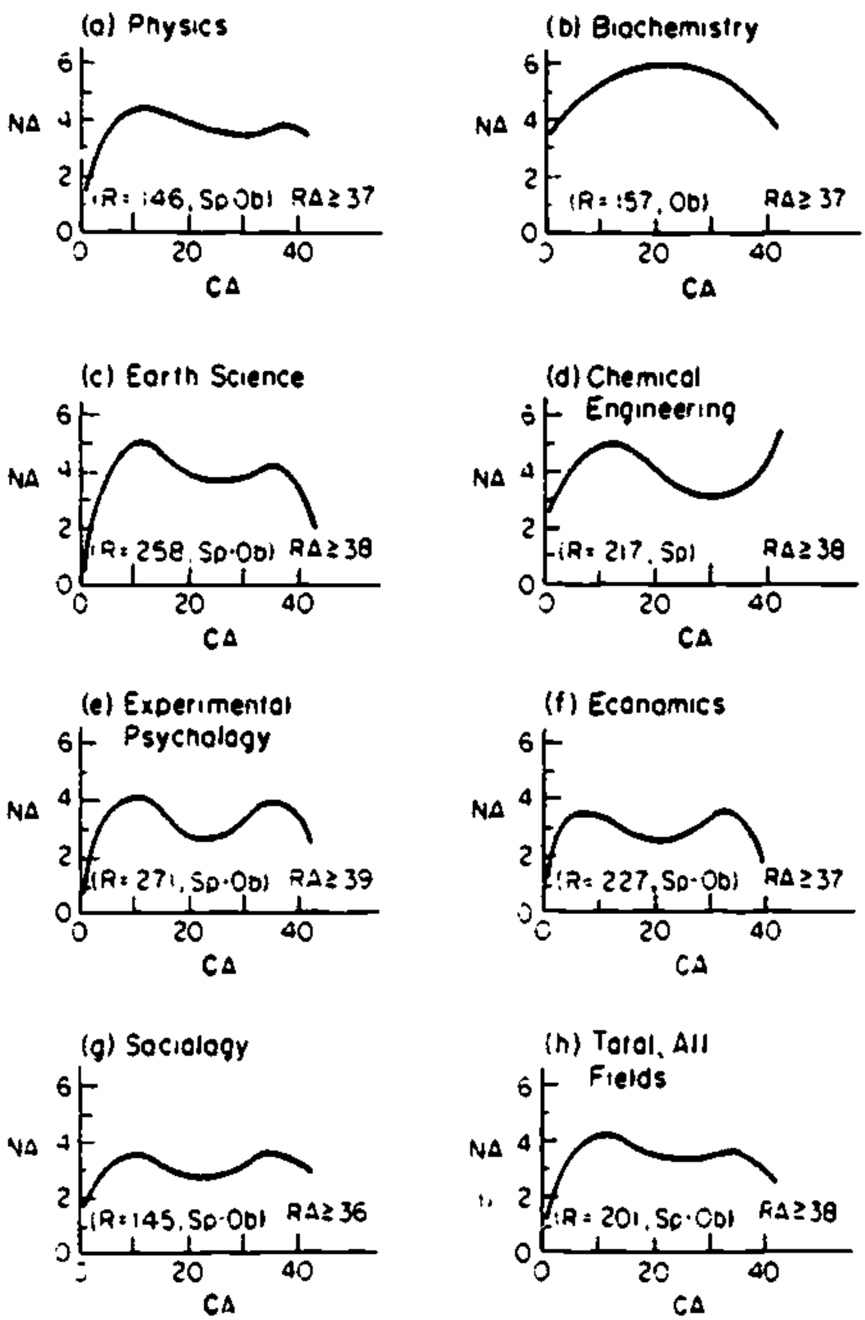


FIGURE 8.2

PLOTS OF BEST-FIT MODEL OF CAREER AGE WITH NUMBER OF PUBLISHED ARTICLES IN LAST TWO YEARS, BY FIELD

NA is number of articles published in last two years.

CA is career age

RA is career age at which retirement is expected

Source: Bayer and Dutton (1977).

Astronomy. Gieryn's (1979b) study of 2,300 American astronomers who had at least one article showed the obsolescence pattern for number of publications with the peak occurring eleven to fifteen years after the Ph.D. year. In a more detailed analysis of two specialty areas in astronomy, Gieryn (1979a) found that recent Ph.D.'s were more likely than older astronomers to move into these highly promising problem areas and that they tended to be slightly more productive than older workers.[6/]

The National Science Board (1977) used experts to identify significant advances during the past twenty years in astronomy, chemistry, mathematics, and earth sciences. The study reported that a disproportionate number of the 21 astronomers whose work was judged to be "innovative" were under 35 years old. This finding and those for the other four disciplines (described below) lend some support to the belief that especially creative work is done disproportionately by younger scientists.

Mathematics. Stern's (1978) analysis of data for 435 university mathematicians and the mathematicians elected to the National Academy of Sciences revealed a spurt function among the university mathematicians, with peaks between the ages of 35 and 39 and after age 60, and the nadir for those in their late 40's.

An exception to the cross-sectional studies reviewed here is S. Cole's (1979) study of the productivity of all 497 mathematicians who received their Ph.D.'s in the late 1940's. Although he concluded that their productivity did not decline significantly over the 25-year period, the data showed a slight spurt-obsolescence pattern, with peaks five to ten and fifteen to twenty years after the Ph.D. Cole found that the proportion who published at least one paper and received at least two citations over each five-year period was quite stable over the 25 years, but the proportion who published nothing increased fron 38 percent to 61 percent.

The National Science Board (1977) study of scientific innovations found that ten of eighteen significant advances in mathematics were by scientists under 35, a group that included about two-fifths of all mathematicians.

[6/] Gieryn recognizes the desirability of controlling for other factors known to affect productivity and kindly consented to make these premature results available when I lamented to him the lack of even zero-order studies of the age-productivity relationship within astronomy.

Because these studies failed to control other relevant variables, they provide very limited support for the common belief that age is especially important for creativity in mathematics.

Consistent with their hypothesis that increasing inequality in the scientific reward structure generates inequality in productivity over time, Allison and Stewart (1974) found more variation in article productivity among their older cohorts of scientists, again suggesting the predominance of social structural factors over biological effects of age.

Chemistry. S. Cole's (1979) data showed an obsolescence pattern in chemists' publication rates, with the highest rates for those in their forties. The National Science Board (1977) study found that young chemists were responsible for a disproportionate number of the 17 advancements judges labelled as major innovations. In view of the limitations in both of these studies, no reason exists to expect consistent results.

Allison and Stewart (1974) observed the same pattern of increasing inequality among their synthetic cohorts of chemists that they found for physicists and mathematicians.

Biochemistry. The biochemists Bayer and Dutton (1977) studied were the only group whose publication pattern showed a simple obsolescence function consistent with both positive effects of experience and increasing access to resources necessary to conduct research early in the career and some deleterious effects associated with increased age. The peak occurred about midcareer, slightly later than for the other disciplines they studied (see Figure 8.2). However, as was true for all seven fields, age was a poor predictor of publication rate, accounting for only two percent of the variance.

Biology. I could not locate any individual-level analyses of the relationship between age and productivity among biologists. The pattern for biologists in Allison and Stewart's (1974) aggregate-level analysis differed from those for physics, chemistry, and mathematics, in that it showed only a very slight increase in article inequality as the synthetic cohorts "aged." The authors suggest that this may be due to lower consensus among biologists on important research questions and poorer communication among practitioners which could inhibit an efficient allocation of rewards according to merit so that scientists best able to convert resources into future performance do not accumulate these rewards.

Earth Sciences. The age-productivity association among Bayer and Dutton's (1977) earth scientists was of the spurt-obsolescence form, with the first peak slightly more pronounced than the second (see Figure 8.2). The data fit the curve better for earth scientists than most of the other disciplines they examined, but age still accounted for only seven percent of the variance in article output.

Young researchers were slightly overrepresented among those who had made important innovations in the earth sciences in the National Science Board (1977) study: researchers under 35 constituted only one-fourth of the discipline but were credited with 37 percent of the important advancements.

Geology. S. Cole's (1979) results show an obsolescence curve for geologists' publications. They peaked between ages 40 and 44 and declined sharply for geologists over age 50.

Engineering and Chemical Engineering. Blackburn (1972) cites a 1969 unpublished study by Cantrell which showed research publications of engineers in a single department dropped off after age 50, although other kinds of productivity increased. Bayer and Dutton's (1977) sample of chemical engineers in academic positions published the most about ten years after the Ph.D. and at the end of their careers (see Figure 8.2). Again, however, age accounted for an inconsequential proportion of the variance.

Psychology. The psychologists whom S. Cole (1979) studied showed the monotonic "obsolescence" pattern similar to his sample of geologists (although their peak productivity occurred slightly earlier, between the ages of 35 and 45). On the other hand, the experimental psychologists in Bayer and Dutton's (1977) sample showed the bimodal, spurt-obsolescence pattern, with a fairly strong slump twenty to twenty-five years after the Ph.D., followed by a resurgence to almost their former peak level (see Figure 8.2). The difference between the two samples in their specialty or institutional location no doubt explains the discrepant results.

Economics. The results for Bayer and Dutton's (1977) economists were quite similar to those for their experimental psychologists, except that the first peak occurred slightly sooner and the length of time between the two peaks was correspondingly greater (see Figure 8.2). However, in neither field did the data fit the curve very well.

Sociology. The curve for Bayer and Dutton's (1977) sample of sociologists was the flattest, indicating little variation across age groups. Insofar as the data showed a pattern, it was of the spurt-obsolescence form (see Figure 8.2). In contrast, S. Cole's (1979) results showed an obsolescence function (which was true for almost all the disciplines he considered) peaking between the ages of 45 and 49. In an earlier study, Axelson (1959) found a similar pattern, except that the point of inflection occurred slightly earlier--about fifteen years after the Ph.D. Here again the greater heterogeneity of Bayer and Dutton's sample of college and university faculty and the concomitant greater likelihood that unproductive individuals would leave academic positions prior to the typical retirement age of faculty in Ph.D.-granting departments may account for the discrepancy between the findings of these studies.

Using a measure of association appropriate for linear relationships, Clemente and Sturgis (1974) found a very weak negative relationship between a sample of sociologists' age and article counts. The clear misspecification of the form of the relationship renders this result of little value.

III. Methodological Problems in Existing Research

Most of the empirical studies reviewed above are flawed by one or more methodological problems. The major one follows from the atheoretical approach underlying most work in this area. Most studies are bivariate: they fail to control statistically for factors that might affect the form of any relationship between scientists' age and their performance, such as the calibre of their training, their early research experience, their organizational location, their primary work activity, the availability of resources, and rewards for research. Pelz and Andrews' (1966) study is an exception. Many early studies failed to take into account something as basic as field of study. In view of Bayer and Dutton's (1977) findings, ignoring discipline vitiates the value of these studies. The generalizability of even those studies that took discipline into account is questionable, in view of the omission of other important variables. Such bivariate studies are particularly problematic because of misleading policy implications. To take one example, if older scientists publish less because they are called upon to carry out administrative duties, as the number of older scientists increases, a smaller proportion would be drawn away from research into administrative positions and the age-productivity association would drop.

A second, equally serious problem characterizes most work on this topic. With the exception of Bayer and Dutton (1977), studies that assessed the strength of association between age and productivity used measures of association that assume a linear association. The literature from Lehman (1936) to Bayer and Dutton (1977) belies this assumption of linearity.

A third major flaw is the failure of most studies to report the magnitude of any association between age and productivity or to test the hypothesis that any association based on sample data could have resulted from sampling error. Both S. Cole's (1979) and Pelz and Andrews' (1966) work suffer from this weakness. In studies that measured the strength of the association, the impact of age was trivial, never accounting for more than seven percent of the variance in productivity. Although a weak association might result from misspecification of the form of the relationship, the zero-order effect of age would almost certainly be further attenuated in more properly specified models that include demonstrated determinants of productivity (e.g., primary work activity, institutional setting, and research resources) which are usually correlated with age.

Fourth, with the exception of S. Cole's (1979) study of mathematicians, findings are based on cross-sectional rather than longitudinal data, so age and generation (cohort) effects cannot be distinguished. Hence, the age-productivity associations might be spurious, with generational differences in socialization, access to resources, and so forth, actually responsible for older cohorts' lower productivity rather than their age. Longitudinal analyses are also necessary to test the hypothesis that the late-career spurt observed in some studies results from the selective attrition of less productive researchers.

Fifth, most studies fail to consider the problem of measuring scientific performance. Neither of the two most common measures--recent article and citation counts--perfectly captures the phenomenon of interest. As scientists mature, they may change their publication patterns from articles to other forms of productivity without a decline in their overall contributions to their field. The validity of citations as measures of productivity may also vary over time. Since citations are a function of both scientists' professional visibility as well as the quantity and quality of their publications, age-related changes in scientists' visibility may affect their citation rates. Other measures such as the number of lifetime publications are patently inappropriate unless cumulative models are assessed, and that exercise would be useful only under limited circumstances. Although space does not permit a full review of studies of other performance measures besides publications, evidence shows that the form of the age-productivity curve depends on the performance criterion examined (Bayer and Dutton, 1977).

Focusing on major scientific innovations rather than simple publication counts may come closer to theoretical expectations about deleterious effects of age or beneficial effects of experience, but difficulties in measuring innovations make considerable demands on researchers.

IV. Conclusions

Despite the limitations in existing research, some general conclusions regarding the relationship between age and productivity are possible. First, neither linear nor other monotonic models adequately described the age-productivity association. In none of the disciplines examined did productivity either increase or decrease monotonically with age or experience. These results cast doubt on any simple aging effect, and it seems safe to conclude that aging is not necessarily accompanied by reduced productivity. This is not to say that publication may not decline at certain points during scientists' careers. Depending on the characteristics of the sample (institutional affiliation, discipline, etc.), various non-monotonic functions ("obsolescence", "spurt" and "spurt-obsolescence") appeared to offer the best description of the zero-order relationship between age and productivity. Moreover, at least the zero-order relationships were often bimodal, with the first peak occurring about ten years after the Ph.D. and the second as scientists approached the end of their careers. These patterns are consistent with selective attrition in which less productive scientists are more likely to retire early or shift into nonresearch positions toward the ends of their careers. Bayer and Dutton (1977) suggested that market factors, generational differences, and selective attrition may all overlay any effects of aging. But here I should reiterate that the magnitude of the observed effects of aging is quite small and would presumably be attenuated further if appropriate predictors known to be related to age were controlled.

As theories of scientific performance suggest, various disciplines or even different samples of scientists from the same discipline yield different results. The failure of any single function to best describe the relationship for the seven fields Bayer and Dutton studied shows that results cannot be generalized across disciplines. Discrepancies between S. Cole's and Bayer and Dutton's findings for the same disciplines preclude generalizing across populations within the same field.

The question of the effect of aging on performance has periodically occupied observers of the scientific enterprise for half a century. It still lacks a definitive answer. Only multivariate studies of specific disciplines based on longitudinal data that allow for nonlinear effects of age will tell us whether aging *per se* exercises any independent effect on scientists' performance. As the scientific population ages, the policy implications of any age-performance relationship become increasingly salient. Perhaps these policy questions will motivate well-crafted, theoretically informed research.

REFERENCES

Allison, P. D. and J. A. Stewart. Productivity Differences among Scientists: Evidence for Accumulative Advantage. American Sociological Review, 39: 595-606, 1974.

Axelson, L. J. Differences in Productivity of Doctorates in Sociology. Journal of Educational Sociology, 33 (October): 49-55, 1959.

Barber, B. Resistance by Scientists to Scientific Discovery. Science, 134: 592-602, 1961.

Bayer, A. E. and J. E. Dutton. Career Age and Research--Professional Activities of Academic Scientists: Tests of Alternative Nonlinear Models and Some Implications for Higher Education Faculty Policies. Journal of Higher Education, 43: 259-282, 1977.

_____. and J. K. Folger, Some Correlates of a Citation Measure of Productivity in Science, Sociology of Education, 39: 381-390, 1966.

Blackburn, R. T. Tenure: Aspects of Job Security on the Changing Campus. Research Monograph No. 19. Atlanta, Georgia: Southern Regional Education Board, 1972.

_____., C. E. Beyhmer, and D. E. Hall. Research Note: Correlates of Faculty Publications. Sociology of Education, 51: 132-141, 1978.

Clemente, F. and R. B. Sturgis. Quality of Department of Doctoral Training and Research Productivity. Sociology of Education, 47: 287-299, 1974.

Cole, J. R. I.Q. and Achievement in American Science. Paper presented at the annual meeting of the American Sociological Association, Montreal, 1974.

_____. and S. Cole, Social Stratification in Science. Chicago: University of Chicago Press, 1973.

Cole, S. Age and Scientific Performance. American Journal of Sociology, 84: 958-977, 1979.

Crane, D. Scientists at Major and Minor Universities: A Study of Productivity and Recognition. American Sociological Review, 30 (October): 699-714, 1965.

Dennis, W. Age and Achievement: A Critique. Journal of Gerontology, 11: 331-337, 1956a.

_____. Age and Productivity among Scientists. Science, 123: 724, 1956b.

_____. The Age Decrement in Outstanding Scientific Contributions: Fact or Artifact? American Psychologist, 13: 457-460, 1958.

_____. Creative Productivity between the Ages of 20 and 80. Journal of Gerontology, 21: 1-8, 1966.

Fulton, O. and M. Trow. Research Activity in American Higher Education. Sociology of Education 47 (Winter): 29-73, 1974.

Gieryn, T. F. Demography of Problem Areas in Astronomy, 1950-75. Read at the 4th Annual Meetings of the Society for the Social Studies of Science, Washington, November 1979a.

_____. Generation Differences in Problem Choices of Sci-ntists. Forthcoming, 1979b.

Hagstrom, Warren O. The Scientific Community. New York: Basic Books, 1965.

Hargens, L. L. Relations between Work Habits, Research Technologies and Eminence in Science. Sociology of Work and Occupations, 5 (February): 97-112, 1978.

_____., B. F. Reskin, and P. D. Allison. Problems in Estimating Measurement Error from Panel Data: An Example Involving the Measurement of Scientific Productivity. Sociological Methods and Research, 4 (May): 439-458, 1976.

Kuhn, T. S. The Structure of Scientific Revolutions. Chicago: University of Chicago Press, 1962.

Lehman, H. C. The Creative Years in Science and Literature. Scientific Monthly, 43: 162, 1936.

_____. Man's Most Creative Years: Quality vs. Quantity of Output. Scientific Monthly, 59: 384-398, 1944.

_____. Age and Achievement. Princeton: Princeton University Press, 1953.

Long, J. S. Productivity and Academic Position in the Scientific Career. American Sociological Review, 43 (December): 889-908, 1978.

National Research Council. Research Excellence through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. Commission on Human Resources. Washington, D.C.: National Academy of Sciences, 1979.

National Science Board. Report to the Subcommittee in Science, Research and Technology, U.S. House of Representatives Regarding Peer Review Procedures at the National Science Foundation. Washington, D.C.: National Science Board, 1977 (NSB 77-468).

Pelz, D. C. and F. M. Andrews. Scientists in Organizations. New York: Wiley, 1966 (revised edition, 1976).

Reskin, B. F. Scientific Productivity and the Reward Structure of Science. American Sociological Review, 42: 491-504, 1977.

_____. Academic Sponsorship and Scientists' Careers. Sociology of Education, 52 (July): 129-146, 1979.

Stern, N. Age and Achievement in Mathematics: A Case-Study in the Sociology of Science. Social Studies of Science, 8: 127-140, 1978.

Taylor, C. W. and F. Barron (eds.) Scientific Creativity: Its Recognition and Development. New York: Wiley, 1963.

Tuckman, H. P. Publication, Teaching and the Academic Reward Structure. Lexington, Mass.: Lexington Books, 1976.

Vroom, V. Work and Motivation. New York: Wiley, 1964.

Zuckerman, H. Scientific Elite: Nobel Laureates in the United States. New York: The Free Press, 1977.

_____. and R. K. Merton. Age, Aging, and Age Structure in Science. In M. W. Riley, M. Johnson, and A. Foner (eds.), Aging and Society. Vol. III: A Sociology of Age Stratification. New York: Russell Sage, 1972.

CHAPTER IX

THE FORECASTER'S ART AND THE "YOUNG INVESTIGATOR" PROBLEM: WHAT WE HAVE LEARNED AND WHAT WE NEED TO KNOW

Fred E. Balderston*
University of California, Berkeley

Michael S. McPherson*
Williams College

The "young investigator" problem presents us with an interesting case study in the application of forecasting models to a significant policy issue. When the Committee on Continuity in Academic Research Performance was called together to investigate this problem, its first step was to convene a workshop in forecasting specialists to help in determining how much was known about the future academic demand for Ph.D.'s in science and engineering. The Committee's work obviously involved much besides the assessment of this quantitative information, including both assessment of the significance for science vitality of changes in hiring rates and the assessment of alternative policies. But plainly, forecasts of future demand were central to the Committee's work, and indeed to the whole notion that a "young investigator" problem exists.[1/]

This paper offers a retrospective look at the adequacy of the available forecasts for answering the kinds of questions the Committee needed to address. This brief paper is neither a comprehensive survey of the literature nor a full report of the proceedings of the Forecasting Workshop. We aim simply to convey a sense of what the collective wisdom of the forecasters was able to contribute to an understanding of the "young investigator"

---

*Fred Balderston chaired the Workshop of Specialists in Forecasts of Demand for Scientists and Engineers, by the National Research Council's (NRC) Committee on Continuity in Academic Research Performance in Washington, D.C., March 31 and April 1, 1979. Michael McPherson directed the Committee's study. The authors wish to thank Porter Coggeshall, Joseph A. Kershaw and William C. Kelly for their comments.

1/ The term "young investigator" problem is a convenient and increasingly familiar label, used for those reasons. But it may be something of a misnomer, since at least as analyzed by the Committee on Continuity, the relevant issue is more the decline in turnover and of new hiring in departments than the "youth" of the faculty *per se* (National Research Council, 1979, chapter 3).

problem, and of what the most significant limitations and uncertainties in presently available forecasts seem to be from the standpoint of this problem.

The hypothesized causal chain which leads to anticipations of a "young investigator" problem is this: basic scientific research is best conducted and is mostly conducted in the universities; with the stabilization and then potential decline of higher education enrollments, universities will be able to hire young doctorates as new faculty only as existing faculty resign, die, or retire, and some universities may even have to reduce the number of faculty; in many fields, the age distribution of existing faculty is skewed to relatively young age brackets because of past concentrated hiring in the 1950's and 1960's, thus the replacement rate will be low; thus, the universities can hire very few young doctorates in most fields in the foreseeable future, unless such hiring can be justified by needs, and financing, other than that based on enrollment; the capacity to continue hiring new faculty is crucial to the creative work of science and engineering departments in universities, partly because of the strong research commitments, fresh training, and possibly the unique creativity of younger faculty, and partly because university departments need "a continuing flow of new blood" to stay current, innovative, and flexible. Therefore, the causal chain implies that in the absence of some special intervention, the vitality of basic scientific research will suffer in many fields because of the lack of participation by young doctorates.

The oncoming supply of new young doctorates is projected to be much larger in most fields than the academic hiring demand, most clearly for the next four of five years during which graduate students already enrolled will be in the pipeline. Students now deciding whether to embark on graduate study in the sciences, however, may well decide in favor of more attractive career alternatives: in physics, mathematics, and some other fields, numbers have already fallen in response to pessimistic career expectations, but at least as worrisome as the question of numbers, for the future, is the question whether the sciences will receive a high share of the most gifted students. On the supply side, then, the hypothesized causal chain is that short-term supply of young doctorates will be more than ample in relation to jobs in academic science, but for the longer term, there may be cause for concern about future quality of new doctorates, if not quantity. Also, if the universities cannot compete in salaries and professional opportunities, they will, in future, fail to attract a high share of the outstanding young doctorates. So much for the supply side.

To what extent was the available forecasting literature able to verify this chain of hypotheses on both the supply side and the demand side of the question? What gaps and inadequacies in our projection methods and results were revealed when that literature was examined?

I. The Basic Forces at Work

It has to be said immediately that the forecasters, both in writing and in person at the Workshop, displayed a surprising amount of agreement about the basic forces at work in shaping the academic demand for science and engineering Ph.D.'s, and even about the quantitative importance of those forces. In the manpower area and in other areas of forecasting, much is made of disagreements among projections, and it is natural that these disagreements should be the center of thought and attention. This phenomenon can easily, however, lead to the wrong impression that our disagreement is total and that we know nothing about the future. This is far from the case.

Thus, in projecting the academic demand for science and engineering Ph.D.'s, the demographic facts pertaining to both students and faculty are of paramount importance, and they are crystal clear. The college-age population has moved from an era of rapid growth in the 1960's to somewhat slower growth in the 1970's to a sharp decline in the 1980's--a decline which will ultimately reach 25 percent by the early 1990's. Even allowing for possible rises in rates of college attendance in the traditional age groups and increasing enrollment of nontraditional groups, few observers expect that enrollment trends will support more than at best a very modest growth in total faculty size over the next 15 years. Thus, hiring of new faculty to accommodate growth in the total higher education system, which has been the most important source of hiring for the last two decades, is likely to be close to nonexistent for the next 15 years. At the same time, rates of hiring of new faculty to replace those who retire or die will be low, because the very rapid growth of faculties in the 1960's implies that many presently tenured faculty are relatively young. This fact is brought out in Figure 9.1, which compares the actual age distribution of science and engineering faculty to a "steady-state" age distribution which would result if faculty hiring rates did not fluctuate over time.

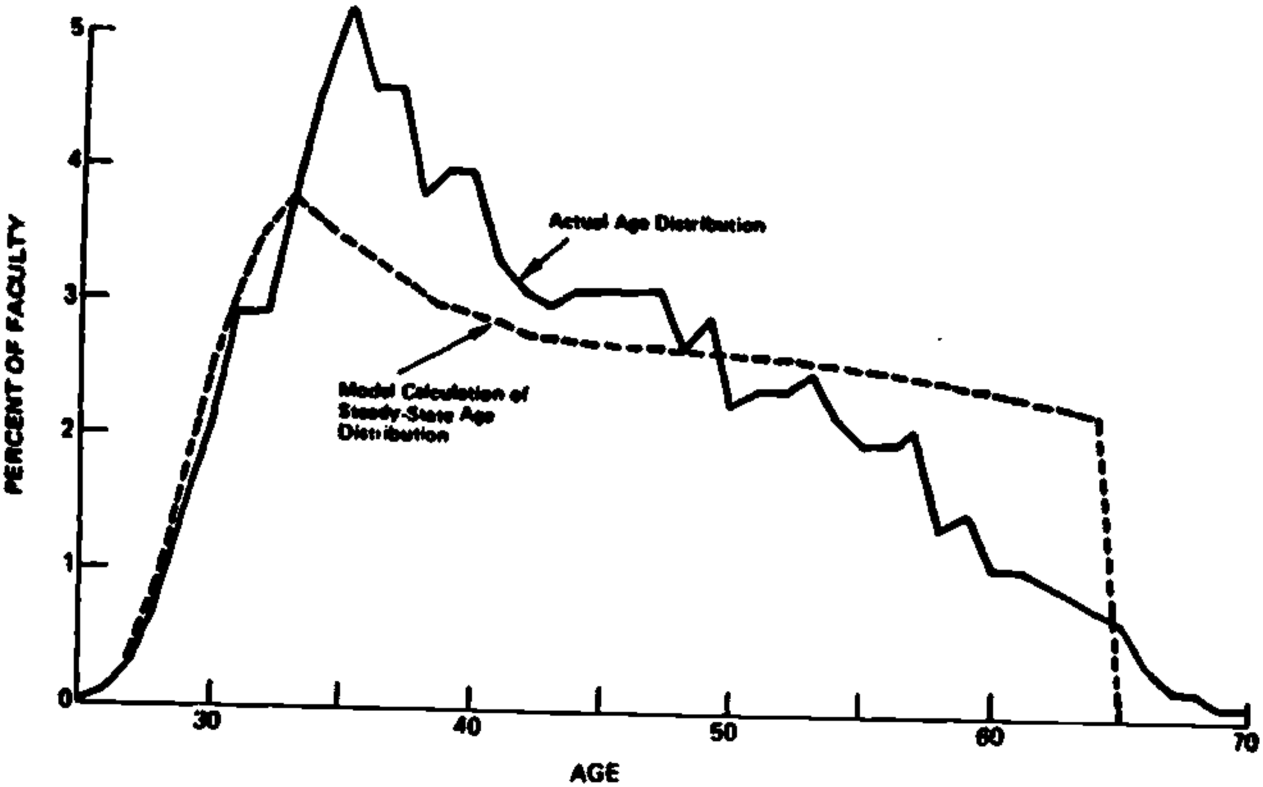
The combination of faculty and student demographics implies both low "replacement" demand and low "growth" demand for new faculty. A sketch of the quantitative implications of these developments, drawn from data in Kuh and Radner's paper in this volume (chapter III), is shown in Figure 9.2. Other studies may differ in the exact magnitude of the projected decline in faculty openings, but most informed observers--including all of the participants at the Workshop--expect such a decline.

This broad agreement on the direction of change is not enough to settle the key questions about the "young investigator" problem, however, for two quite different kinds of reasons. First, even if we knew all we wanted to know, in full detail, about the future course of academic hiring (and plainly we don't), we would not, from those data alone, know whether those rates of hiring were "good" or "bad" for American science. How important is it to have young scientists, or to have an influx of "new blood" into academic science departments? How important is it to research vitality that young scientists work in universities, rather than industry or government--or that young university scientists hold faculty positions, rather than "soft money" research positions of one sort or another? These difficult questions were central in the report of the Committee on Continuity, and the bearing of sociological research on some of them is discussed in Barbara Reskin's paper in this volume (chapter VIII). These questions, however, reach beyond the forecaster's art, and beyond the scope of this paper.

The second set of considerations is much more relevant to forecasting. For knowing broadly that the basic forces at work in faculty labor markets

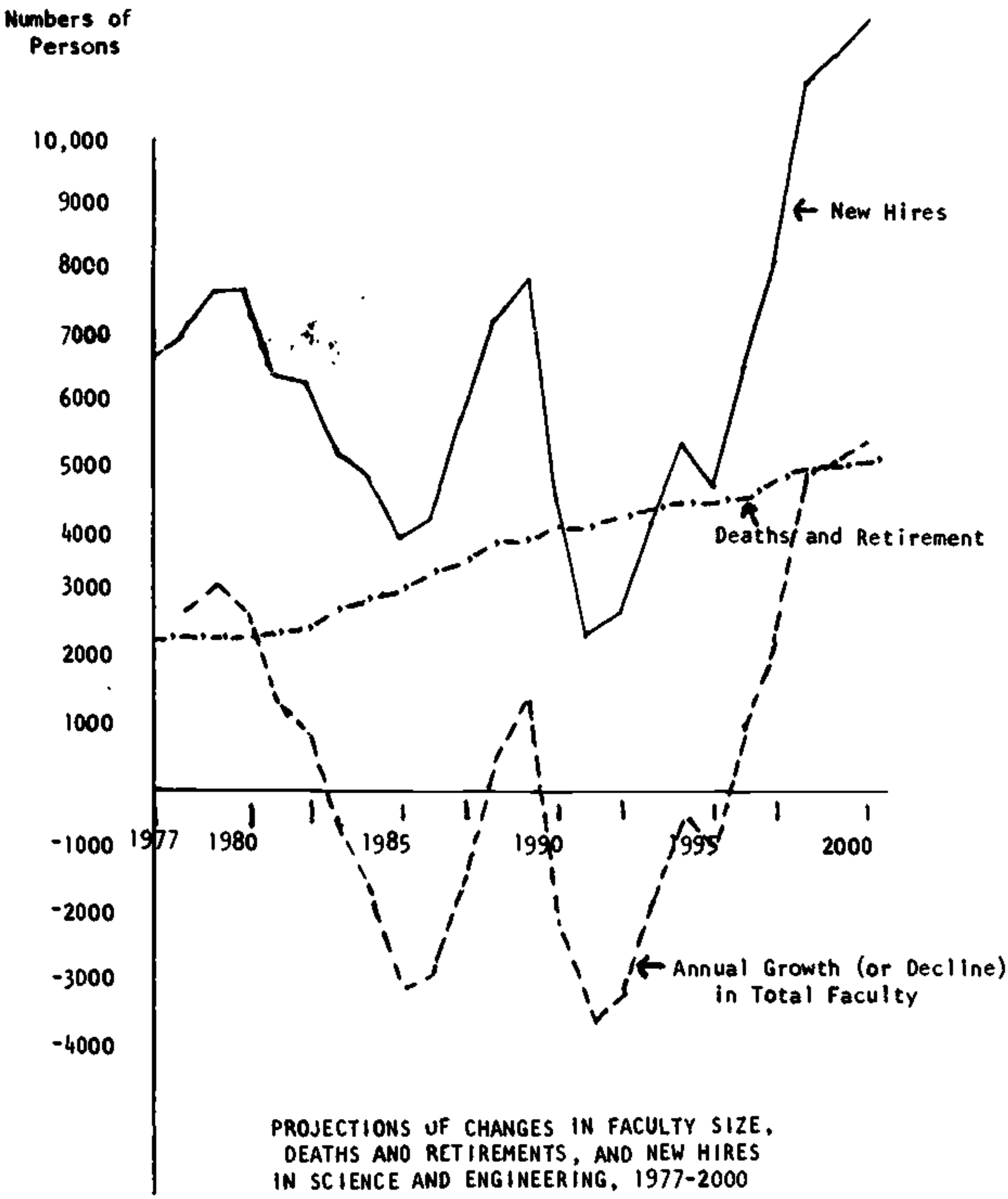
FIGURE 9.1

ACTUAL AND STEADY-STATE AGE DISTRIBUTIONS, FULL-TIME DOCTORAL FACULTY AT PH.D.-GRANTING INSTITUTIONS, 1978



Source: National Research Council, 1979, p. 18

FIGURE 9.2



PROJECTIONS OF CHANGES IN FACULTY SIZE, DEATHS AND RETIREMENTS, AND NEW HIRES IN SCIENCE AND ENGINEERING, 1977-2000

Source: Kuh and Radner, Reconcilable Differences?, Appendix I and unpublished data point toward reduced demand still leaves open a number of questions which are vital for policy:

- which scientific fields and which kinds of universities and colleges will be most severely affected?
- to what extent will the responses of universities and other employers, and of actual and prospective faculty members, to worsening market conditions change the expected outcomes?
- when will the expected declines in faculty hiring occur, and how long will they last?
- what effect will the changing market situation have on the quality and not merely on the numbers of new faculty?

All of these questions--which we might label the problems of disaggregation, behavioral response, time profile, and quality--have an obvious bearing on policy. None of them, in the present state of the forecasting art, can be answered with full confidence. It is, in fact, probably fair to say that it is less the case that forecasters disagree about the answers to these questions than that they agree that they don't know much. In the next section, we discuss what we don't know and why.

II. Types of Uncertainty Underlying the Forecasts

Disaggregation

Most observers including all the Workshop members, agreed that disaggregation by field is important in assessing the seriousness of the "young investigator" problem and in designing any young-investigator policy, for the fields do differ in the likely severity and duration of decline in hiring opportunities. Further, it is plain that disaggregated, field-by-field administration of any policy, once adopted and funded, is essential if really good effect is to be achieved. (Related to this, but going beyond the realm of forecasting, is the need for much more detailed understanding of the pattern of organization of basic science and the place of young doctorates in it, field by field; such understanding ought to be a basic long-term objective of research into the social structure of science.)

It is possible to obtain reasonably good (though not fully adequate) data on the current age distribution of doctoral faculty by relatively broad fields (physics, mathematics, etc.), and from such data reasonable estimates of replacement demand by field can be made. Projecting changes in the number of faculty required for teaching is, however, much chancier and less satisfactory. For some fields, the demand for teaching may be closely tied to the number of majors, and projecting the future course of undergraduate choices of major is not much more scientific than projecting future hair styles. In other fields, including mathematics, much of the teaching load is in service courses which are not taken mainly by majors. In such fields, demand may be affected by broad shifts in choice of major and by changing patterns of university "general education" requirements.

Uncertainties about such factors put real limits on the accuracy of long-term forecasts of demand for faculty in specific fields, and the uncertainties become greater as fields are more narrowly defined. Perhaps surprisingly, we know more about the future demand for faculty as a whole than we do about the division of faculty among fields. The kind of short-term forecasting by specific fields required to administer a program like that proposed in the National Research Council (NRC, 1979) report is, however, probably more feasible, because patterns of student choices are unlikely to fluctuate widely over short periods.

More fundamental issues are raised by the problem of disaggregating forecasts of faculty demand at different classes of universities and colleges. Few observers expect the impact of declining college-age population on undergraduate enrollment to be shared equally among various categories of colleges and universities. There seems to be a general view (though in our view, a doubtful one) that public institutions will fare better than private, and a better grounded view that the more "elite" and prestigious institutions in both the public and private sectors will do better in maintaining their enrollments than other institutions.

Since it is apparent that a relative handful of institutions account for the bulk of academic scientific research, and since disproportionately many of these institutions are in the "elite" category, forecasts of faculty demand disaggregated by class of institution would plainly be desirable. Some work of this kind has been done in an ad hoc way--for example, by Grodzins in the present volume (chapter VI) when he assumes that physics enrollments in Ph.D.-granting institutions will stay roughly constant and will fall significantly elsewhere. More systematic approaches to the problem will require a better analysis of the underlying patterns of student choice among institution types, and of responses by different types of colleges and universities to changing conditions. So far, the quantitative literature on enrollment demand has not proved very helpful in this regard; the best available pieces remain speculative and judgmental.[2/]

While trends in the size of the age-group population are important, other factors also affect aggregate enrollment demand and its probable distribution by type of institution and even by undergraduate major. An increase is projected in the proportion of ethnic and racial minorities in the youthful population; historically, these minorities have had lower than average college-going rates, as have children of low-income families. Further, the sciences and engineering face special problems in this marked environment both to attract minorities and to attract more women students, traditionally a low enrollment component.

Differences in enrollment trends by geographical region are likely to favor the Southeast, the Southwest, and the Far West. Private higher education is relatively concentrated in those regions which are likely to experience greater enrollment declines. The prominent research universities are quite heavily represented in the Midwest and the Northeast. These institutions will have to compete very vigorously for enrollment if they are to fare well in maintaining faculty positions. Very few institutions are immune to changes in the depressant pressures on undergraduate enrollment in their own region.

[2/] For a useful informal discussion, see Carnegie Foundation for the Advancement of Teaching, 1975. For a review of the literature, see McPherson, 1978.

Behavioral Responses

Institutions and individuals are likely to respond to the declining academic demand for Ph.D.'s in ways that make more academic positions available, thus partially offsetting the decline in demand. This can happen in many ways: relatively lower academic salaries and perhaps poorer working conditions will cause some tenured people to leave academic careers in search of greener pastures. (The availability of nonacademic jobs will obviously vary across fields. A general worry is that, in any particular field, professors who are more "marketable" may also be more lively and interesting; academic science may tend differentially to lose its more valuable people.) Universities, finding professors cheaper, may employ more of them per student. (Rising costs for energy and other items and the strenuous competition for students will, however, introduce a counterpressure on university budgets.) To keep costs down and to keep up a steady flow of young faculty, more universities may adopt a kind of "revolving door policy" for assistant professors by making very few promotions to tenure. (Conceivably, this could "solve" the "young investigator" problem only to produce damage to the morale of young faculty and rapid aging in the tenured ranks.) Finally, universities might replace non-Ph.D.'s on their faculties with Ph.D.'s as Ph.D.'s become cheaper. (There is not much room for this at Ph.D.-granting institutions.)

There is not much doubt that these behavioral responses are real; the important question is how big and how fast they are, and to what degree they may be offset by other forces. These are essentially empirical questions, but they are extraordinarily hard to answer. The relevant elasticity coefficients have to be teased out of historical data in which everything varies simultaneously; Richard Freeman's paper in this volume (chapter V) shows both the subtlety and imagination of some economists' attempts to measure these effects, and the difficulty of getting fully convincing specifications and reliable results. Further, it is particularly dangerous to apply coefficients estimated from the recent past of American higher education to its future. The environment of higher education in the

1980's will be so different from that of the 1960's that one suspects that many behavioral coefficients and other features of the structure of models of higher education will change importantly in ways that are hard to predict. One simple example: when engineering enrollments fell in the early 1970's, more than one university felt able to maintain the size of its engineering staff both because it anticipated an eventual rebound of enrollments and because the university as a whole was reasonably prosperous. It would be foolish to expect similar "slack" in the ratio of faculty to students when enrollment drops are more widespread at a university and when budget stringencies are greater.

The obvious point that emerges from this is the importance of being clear about assumptions in doing forecasts, and the importance of analyzing the sensitivity of the results to changes in the assumptions.[3/]

Quality

Most observers expect the anticipated decline in demand for new faculty in many science and engineering fields will lead to further declines in relative faculty salaries[4/] and to increased competition for the jobs that are available. The further worry is that this unfavorable labor market may disproportionately discourage the more able potential scientists from pursuing academic careers. A decline in the quality of scientific personnel might damage severely the effectiveness of both the teaching and research efforts of colleges and universities.

In fact, one already hears quite a bit of speculation around universities that this phenomenon can already be detected in some fields--both in the career choices of the best undergraduates and in the quality of graduate students and candidates for faculty positions. But this question has received almost no systematic study.

Theoretically, a decline in the number of faculty job openings could result in either a rise or a decline in the average "quality" of those hired

---

[3/] Allan Cartter (1976) remains an outstanding example of such work.

[4/] Studies by the American Association of University Professors and others indicate that real faculty salaries have already fallen on the order of 25 percent in the 1970's.

(granting some measure of quality). For, while the total pool of candidates is likely to shrink if job openings are fewer, the number selected from the pool will shrink as well. The key question is the _relative_ responsiveness of more and less able potential faculty to a perceived decline in job opportunities. And this can be argued either way: perhaps the more able candidates will also prove more "dedicated" and more confident of ultimate success, and hence will continue to pursue academic careers; or, perhaps the more able candidates also have the best nonacademic alternatives, and so will disproportionately withdraw from the academic labor market. Which effect will dominate is an empirical question that cannot be settled _a priori_.

There seems to be no good reason why this question of relative responsiveness of students of differing abilities to changing conditions in the academic labor market could not, in fact, be studied empirically. This might be done in at least two ways. One approach is to relate changes in the pattern of career choice among some well-defined group of high-quality undergraduates (e.g., members of Phi Beta Kappa or high-ranking graduates of prestigious colleges) to changes over time in salaries and job opportunities among professions. Another approach (probably less effective in isolating specifically the effect of changing job opportunities on career choice of the more able) is to examine variation over time in the "quality" (as measured say by Graduate Record Examination scores) of entering classes of graduate students in various fields of science.[5/] Given the vital importance commonly attached to high-quality personnel in the performance of science, studies of this kind seem well worth undertaking.

Timing

The expected downturn in academic demand for scientists is pretty clearly a temporary phenomenon--likely to ease at least by the 1990's, when enrollments and retirement rates are expected to have begun increasing again. But exactly when, over the next 20 years, the downturn will be deepest is less clear. It is often not appreciated, for example, that there is actually

---

[5/] Basic data of this sort have been published for chemistry. See Chemical and Engineering News, December 17, 1979, p.17.

a "double dip" in the size of the 18 to 21-year-old population: there is a large and abrupt drop in the early 1990's which makes the late 1980's dip look relatively modest by comparison.

One key factor affecting the timing is the relative importance that should be attached to, on the one hand, low retirement rates and, on the other hand, to declining enrollments, in forecasting faculty demand. Retirment rates are at their lowest in most fields in the early to mid-1980's and rise gradually thereafter; the serious declines in college-age population do not occur until the late 1980's and early 1990's (see Figure 9.2). Thus, the "shortage" of openings produced by retirements is a relatively near-term phenomenon and relatively clear-cut; the effect of demographic declines, though potentially more severe, is further away and--especially for research universities which may be better positioned to avoid enrollment cuts--more speculative.

The uncertainties surrounding the time pattern of variations in faculty demand have implications both for projection methodology and for policy. Regarding projection methodology, there is the question (pressed hard at the Forecasting Workshop by Gus Haggstrom) whether to report a full series of annual projections (as Radner and Kuh do) perhaps imparting a sense of spurious accuracy to projections of yearly fluctuations; or, whether it is better to report only results for selected years (as the NSF projections do). The disadvantages of the latter approach are, first, that it suppresses what may be useful information about the overall "shape" of the time pattern, and, second, that picking out a single year may mis-represent even average experience over a period of years when there are significant annual fluctuations. On balance, it seems best to produce and report annual projections, with large and prominent warnings that taking annual fluctuations too seriously may be hazardous to the readers' health.

On the policy side, uncertainties in the long-term time paths of hiring variations pretty clearly imply that any policy aimed to counteract adverse effects of these fluctuations must be flexible enough to allow for readjustment of conditions which diverge substantially from those expected, and further, that any such policy should be designed to terminate when adverse conditions have ended. It is probably also true, as David Breneman argued at the Workshop, that--technical questions aside--it is politically unrealistic to rely on a program which requires for its effectiveness highly sophisticated calibrations of its funding levels to annual fluctuations in forecasted market conditions. The Junior Scholars Program was originally presented by Radner and Kuh in a way that implied such sensitive calibration was essential.

IV. Conclusion

This review of the problems of forecasting may be summed up with the observation that there is a strong qualitative finding as to the future direction of hiring and retention of young scientists in academic positions: without some policy intervention, the number of those hired each year into meaningful academic posts during most of the next decade or more will be well below the recent hiring rates, and well below the numbers of new doctorates seeking regular positions in academic science.

The size of the young scientist problem in the aggregate and for each scientific field is, however, a resultant of many factors in combination. There is a sizeable zone of uncertainty surrounding hiring demand projections. In addition, the timing of changes in the numbers of places available annually is subject to uncertainties. Further intensive study of the determinants of both demand and supply is very much needed, and such study should in time enable policy makers to design more precisely targeted and closely timed interventions than can now be designed with full confidence.

At the same time, the forecasting efforts that have been undertaken are quite sufficient as a qualitative basic for policy interventions. The forecasts currently available do give us a view of the future: but each projection should be regarded as a statement that is conditional upon the realization of a configuration of assumptions and estimated parameter values.

Because the basic direction of change is quite clearly evident from the studies now available, we conclude that policy interventions are indeed warranted. At the same time, the conditional character of the available forecasts makes it necessary to design these policy interventions so that they will not depend too exactly on the accuracy of forecasts. In addition, the need for further insight and evidence is clear, and it will be worthwhile to invest in continuing research and analysis of this problem, as well as careful monitoring of the results of those new programs that are adopted.

The uncertainties buttress the argument for stage-by-stage programming of interventions to determine when to change the magnitude and composition of these programs. This approach should take adequate advantage of the knowledge gained from forecasting and further analytical investigation of the problem, and it should reduce what otherwise might be large overshoots or shortfalls in the policy interventions that are adopted.

REFERENCES

Carnegie Foundation for the Advancement of Teaching. More than Survival: Prospects for Higher Education in a Period of Uncertainty. Jossey Bass, 1975.

Cartter, A. M. Ph.D.'s and the Academic Labor Market. New York: McGraw Hill, 1976.

McPherson, M. The Demand for Higher Education, in D. Breneman and C. Finn (eds.), Public Policy and Private Higher Education, Washington, D.C.: The Brookings Institution, 1978.

National Research Council. Commission on Human Resources. Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research. Washington, D.C.: National Academy of Sciences, 1979.

"Quality of Chemistry Grad Students Failing." Chemical & Engineering News, 57, (December 17, 1979): 17.

APPENDIX A

AGENDA OF WORKSHOP OF SPECIALISTS IN FORECASTS OF
DEMAND FOR SCIENTISTS AND ENGINEERS AND
LIST OF PARTICIPANTS

NATIONAL RESEARCH COUNCIL
COMMISSION ON HUMAN RESOURCES
2101 Constitution Avenue Washington, D C 20418

COMMITTEE ON FUTURE DEMAND FOR YOUNG INVESTIGATORS
IN SCIENCE AND ENGINEERING

WORKSHOP OF SPECIALISTS IN FORECASTS OF DEMAND
FOR SCIENTISTS AND ENGINEERS

APRIL 30 - MAY 1, 1979

Joseph Henry Building, Room 200A
21st and Pennsylvania Avenue, N.W.
Washington, D.C.

Chairman: Frederick E. Balderston

TENTATIVE AGENDA

April 30, 9:00 a.m. - 12:30 p.m.

Papers to be reviewed: Ph.D. Manpower: Employment Demand and Supply 1972-1985, Bureau of Labor Statistics, 1975

Oversupply of Ph.D.'s to Continue Through 1985, Bureau of Labor Statistics, 1978

The Overeducated American and other studies, Richard Freeman

Reviewers: Neal Rosenthal, David W. Breneman

Discussants: Robert McGinnis, Roy Radner

April 30, 1:30 p.m. - 5:00 p.m.

Papers to be reviewed: Personnel Needs and Training for Biomedical and Behavioral Research, National Research Council

Supply and Demand for Biomedical Manpower: 1977 Survey. Preliminary Report, Westat, Inc.

Supply and Demand for Physicists, Lee Grodzins

Reviewers: Allen Singer, William Morsch, Lee Grodzins

Discussants: Stephen P. Dresch

<u>May 1, 9:00 a.m. - 12:30 p.m.</u>

Papers to be reviewed: <u>Projections of the Supply and Utilization of Science and Engineering Doctorates, 1982 and 1987,</u> National Science Foundation

<u>Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000</u>, Carnegie Council of Policy Studies in Higher Education

<u>Projections of Educational Statistics to 1985-1986</u>, National Center for Education Statistics

Reviewers: Charles Falk, Charlotte Kuh, Rolf Wulfsberg

Discussants: Joseph Froomkin, Richard D. Anderson

<u>May 1, 1:30 p.m. - 4:00 p.m.</u>

Summary of Workshop Proceedings - by Frederick E. Balderston, Chairman

General Discussion

NATIONAL RESEARCH COUNCIL

COMMISSION ON HUMAN RESOURCES

Workshop of Specialists in Forecasts of
Demand for Scientists and Engineers

April 30-May 1, 1979

LISTS OF PARTICIPANTS

Richard D. Anderson
Department of Mathematics
Louisiana State University

Frederick E. Balderston
Center for Research in Management Science
University of California

David W. Breneman
Brookings Institution

Steven P. Dresch
Department of Economics
Yale University

Charles E. Falk
Director, Division of Science
Resources Studies/STIA
National Science Foundation

Joseph Froomkin
Joseph Froomkin, Incorporated

Debra Gerald
Division of Postsecondary and
Vocational Education Statistics
National Center for Education Statistics

Lee Grodzins
Department of Physics
Massachusetts Institute of Technology

Eve Katz
Director of Federal Relations
for Graduate Education
Association of American Universities

Charlotte V. Kuh
Graduate School of Education
Harvard University

Robert McGinnis
Department of Sociology
Cornell University

William Morsch
Westat, Inc.

Roy Radner
Harvard University
Kennedy School of Government

Neal Rosenthal
Bureau of Labor Statistics

Allen M. Singer
Commission on Human Resources
National Academy of Sciences

Members of Committee on Continuity in Academic Research Performance

Robert M. Bock, Chairman
Dean, Graduate School
University of Wisconsin

Felix E. Browder
Department of Mathematics
University of Chicago

Gus W. Haggstrom
The Rand Corporation

Donald J. Hernandez
Department of Sociology
University of South Carolina

Jerry Miner
Department of Economics
Syracuse University

Staff of Commission on Human Resources

Porter E. Coggeshall
Project Director, Study of Post-doctorals in Science and Engineering

Dorothy M. Gilford
Director, Human Resources Studies

Harold Goldstein
Consultant, Committee on Continuity in Academic Research Performance

William C. Kelly
Executive Director, Commission on Human Resources

Michael McPherson
Consultant, Committee on Continuity in Academic Research Performance

Kathryn Swafford, Staff Associate
Committee on Continuity in Academic Research Performance

Other National Research Council Staff

Edwin D. Goldfield
Executive Director
Committee on National Statistics

Agency Representatives

Charles Dickens
Group Director, Supply and Education Analysis Group
National Science Foundation

Stanley Turesky
Office of Planning and Analysis
National Endowment for the Humanities

Larry Lacy
Supply and Education Analysis Group
National Science Foundation

APPENDIX B

LIST OF MEMBERS OF THE COMMITTEE ON CONTINUITY IN ACADEMIC RESEARCH PERFORMANCE

COMMITTEE ON CONTINUITY IN ACADEMIC RESEARCH PERFORMANCE

Dr. Robert M. Bock, Chairman
Dean of the Graduate School
University of Wisconsin - Madison

Dr. John A. Beekman
Department of Mathematical Sciences
Ball State University

Dr. Felix E. Browder
Professor of Mathematics
University of Chicago

Dr. Robert Christy
Vice President and Provost
California Institute of Technology

Dr. Allen F. Donovan
Consultant (Senior Vice President, Technical, The Aerospace Corporation, Retired)

Dr. Ronald Geballe
Dean of the Graduate School and Vice Provost for Research
University of Washington
Seattle, Washington

Dr. H. S. Gutowsky
School of Chemical Sciences
University of Illinois, Urbana

Dr. Gus W. Haggstrom
Senior Statistician
Department of Economics
The Rand Corporation

Dr. Donald J. Hernandez *
Staff Associate
Social Science Research Council
Center for Coordination of Research on Social Indicators
Washington, D.C.
* on leave from Department of Sociology University of South Carolina

Dr. William M. Jackson
Professor of Chemistry
Howard University

Dr. Ellen J. Langer
Department of Psychology and Social Relations
Harvard University

Dr. Jerry Miner
Professor of Economics
Syracuse University

Mr. Charles A. Mosher
Public Programs Manager
American Association for the Advancement of Science

Dr. Barbara F. Reskin
Associate Professor of Sociology
Indiana University
Bloomington, Indiana

Dr. Neena B. Schwartz
Deering Professor
Department of Biological Science
Northwestern University

Study Director:
Dr. Michael McPherson
Department of Economics
Williams College